行政院所屬各機關因公出國報告書

（出國類別：~~(參訪)~~ 其他）

航空生理訓練裝備「空間迷向訓練機」之運動平台系統設計審查會

服務機關：國防部中山科學研究(一所)

出國人 職 稱：上校技正
薦聘技士
中校技士
簡聘技正

姓 名：杲中興
倪志文
楊中強
趙思本

出國地點：荷蘭、奧地利、英國

出國期間：90年06月04日至90年06月17日

報告日期：90年09月14日

ASRD-90E-005

國外公差報告

中山科學研究院

國外公差心得報告

批			示	
(二)(一)應加強院內相關單位間資訊交流，可設量擇辦院內有關模擬技術發展研討會。金度 1009 副院長 仲澤勝 1115				
公差 年度	九十	所屬單位 各級主管	政戰部	企劃處
單位	一所模擬組 一所模擬組 一所模擬組 一所模擬組	第一研究所 所長 張元彬 0921	已完成資料審查。	批示後，請將報告裝訂一份紙本及電子檔送交貴所專責人員後轉交本處科技資料組。
級職	簡聘技正 中校技士 薦聘技士 上校技正	第一研究所 組長 杲中興 0914 1315	政治作戰部 保防員 顧中深 1006 1100 政戰部安全組 副組長 蔡昇祥 1008 1105	企劃處 副處長 郭永聖 企劃處 技正 蔣雅倫 1002 1400 沈從正 1002 1500
姓名	趙思本 楊中強 倪志文 杲中興			

補呈 宋副院長閱 大偉

(九〇)一所行會191號

企劃處 90.9.25 收文章

國外進修(公差)人員返國報告主官(管)審查意見表

本所模擬組受軍醫局航空生理訓練中心之委託，負責承製空間迷向機、逃生彈射訓練器及夜視力夜視鏡訓練器等三項裝備，此次國外差旅即針對空間迷向機之運動平台系統購案，前往承製商奧地利 AMST 公司參加系統設計審查會。本組現正自行研發 PC 級影像產生器及平行光顯像系統，此兩項技術屬當今模擬器產業中之頂尖技術，除可降低模擬器之建構成本，並可增加視效影像之逼真度，因此利用會議結束後，前英國 SEOS 公司瞭解平行光顯像系統之設計與驗證，及至英國 PRIMARY IMAGE GRAPHICS 公司瞭解 PC 級影像產生器及其相關週邊配置之性能驗證。

此次國外公差的成效良好，與運動平台系統承製商奧地利 AMST 公司面對面研討系統設計規格、及與國內製作裝備間的界面設計，並於會中指示全案設計的關鍵處及 AMST 公司在設計上的缺失處，雙方在密集的討論後，也得到明確的解決方案。且雙方也具要讓本案能如期如質完成的共識。

因本組之前均無 PC 級影像產生器及平行光顯像系統之性能驗證的相關技術，及運用此兩項技術於模擬器之全系統整合經驗。藉由此次前往英國 SEOS 公司詳細瞭解平行光顯像系統之設計與驗證方式，及至英國 PRIMARY IMAGE GRAPHICS 公司瞭解 PC 級影像產生器及其相關週邊配置之性能驗證。有助本組完成開發 PC 級影像產生器及平行光顯像系統此兩項技術，及日後空間迷向訓練機全系統整合驗證工作之推展。

第一研究所所長張元彬
.921

第一研究所副所長吳中興
0914
1315

依本院 85.11.25（85）迺箐字 15378 號令，返國報告上呈時應附主官評審意見

報　告　資　料　頁

報告編號：	2.出國類別：	3.完成日期：	4.總頁數：
ASRD-90E-005	其他 （參 訪）	90 年 09 月 14 日	本文 37 頁 (含附件共約餘 200 頁)

5. 報告名稱：

航空生理訓練裝備「空間迷向訓練機」之運動平台系統設計審查會

6.核准文號	人令文號	(90)銓鑑 003857 號
	部令文號	
7.經　費		新台幣：707,017 元
8.出(返)國日期		90 年 06 月 04 日至 90 年 06 月 17 日
9.公 差 地 點		荷蘭、奥地利、英國
10.公 差 機 構		中山科學研究院第一研究所
11.附　記		

行政院所屬各機關因公出國報告書

（出國類別：其他 (參訪)）

航空生理訓練裝備「空間迷向訓練機」之

運動平台系統設計審查會

服務機關：國防部中山科學研究(一所)

出國人　職　　稱：上校技正
薦聘技士
中校技士
簡聘技正

姓　　名：杲中興
倪志文
楊中強
趙思本

行政院研考會/省(市)研考會編號欄

出國地點：荷蘭、奧地利、英國

出國期間：90 年 06 月 04 日至 90 年 06 月 17 日

報告日期：90 年 09 月 14 日

行政院及所屬各機關出國報告提要

出國報告名稱：航空生理訓練裝備「空間迷向訓練機」之運動平台系統設計審查會

頁數 200　含附件：□是□否

出國計畫主辦機關/聯絡人/電話

國防部中山科學研究院第一研究所/倪志文/(04)22523051 分機 503780

出國人員姓名/服務機關/單位/職稱/電話

杲中興/國防部中山科學研究第一研究所/模擬組/上校技正/(04)2523051 分機 503530
倪志文/國防部中山科學研究第一研究所/模擬組/薦聘技士/(04)2523051 分機 503780
楊中強/國防部中山科學研究第一研究所/模擬組/中校技士/(04)2523051 分機 503774
趙思本/國防部中山科學研究第一研究所/模擬組/簡聘技正/(04)2523051 分機 503762

出國類別：□1 公差□2 進修□3 研究□4 實習■5 其他：參訪

出國期間：　出國地區：
90.06.04 至 90.06.17 荷蘭、奧地利、英國

報告日期：
90.07.31

分類號/目

關鍵詞：航空生理訓練裝備、空間迷向訓練機、運動平台系統、

內容摘要：（二百至三百字）

依據國防部八九年五月二十五日（八九）常帝三七０二號令核定「國軍岡山醫院航空生理訓練裝備五年投資綱要計畫暨總工作計畫、八九及九０年度工作計畫」，由中科院負責「空間迷向訓練機」籌建工程。

由於空間迷向訓練機需使用運動平台系統來提供空間迷向之動態模擬，因此運動平台系統為空間迷向訓練機之關鍵裝備。運動平台系統所包含的裝備有六軸動感平台、旋轉軸座、操縱桿力感控制器、部份座艙操縱機構、及電子滑環。本組為爭取研發時程及採用市場現有之高效能產品，故將運動平台系統以購案方式，委由奧地利 AMST 公司製造(原購案號碼：XW90149)，其中六軸動感平台及操縱桿力感控制器由 AMST 公司向荷蘭 FOKKER 公司採購裝備，再行組裝測試。本組為祈能如期如質完成運動平台系統交運，以配合後續空間迷向訓練機之全系統整合驗證，故於購案中明訂承廠商應於合約簽署後三個月內安排舉行系統設計審查會，六個月內安排舉行系統整合審查會。以使本組能全程瞭解運動平台系統之設計、製作、及界面整合工作。

另於設計審查會後，安排至英國 SEOS 公司及 PRIMARY IMAGE GRAPHICS 公司等二處拜會。這二家廠商均為當今世界上在模擬器相關產業界中之翹楚，參訪的目的在瞭解其視效系統設計及整合，以助本組於日後之運動平台系統之接收驗證及空間迷向訓練機全系統整合驗證工作之推展。另瞭解該公司之新產品研發情況，做為本組日後專案之參考。

行政院及所屬各機關出國報告審核表

<table>
<tr><td colspan="2">出國報告名稱：航空生理訓練裝備「空間迷向訓練機」之
運動平台系統設計審查會</td></tr>
<tr><td colspan="2">出國計畫主辦機關名稱：國防部中山科學研究第一研究所</td></tr>
<tr><td colspan="2">出國人姓名/職稱/服務單位：杲中興等四人/上校技正/模擬組</td></tr>
<tr><td>出國計畫主辦機關審核意見</td><td>☑1. 依限繳交出國報告
☑2. 格式完整
☑3. 內容充實完備
☑4. 建議具參考價值
☑5. 送本機關參考或研辦
□6. 送上級機關參考
□7. 退回補正，原因：□①不符原核定出國計畫 □②以外文撰寫或僅以所蒐集外文資料為內容 □③內容空洞簡略 □④未依行政院所屬各機關出國報告規格辦理 □⑤未於資訊網登錄提要資料及傳送出國報告電子檔
□8. 其他處理意見：</td></tr>
<tr><td>層轉機關審核意見</td><td>□同意主辦機關審核意見 □全部 □部分（填寫審核意見編號）
□退回補正，原因：__________（填寫審核意見編號）
□其他處理意見：</td></tr>
</table>

企劃組 政戰(?)

資料管理員 江秋霞 0920 0900

第一研究所保防官 周繼勳 0921 0930

說明：

一、出國計畫主辦機關即層轉機關時，不需填寫「層轉機關審核意見」。

二、各機關可依需要自行增列審核項目內容，出國報告審核完畢本表請自行保存。

三、審核作業應於出國報告提出後二個月內完成。

目　　錄

壹、 出國目的及緣由

依據國防部八九年五月二十五日（八九）常帝三七０二號令核定「國軍岡山醫院航空生理訓練裝備五年投資綱要計畫暨總工作計畫、八九及九０年度工作計畫」，由中科院負責「空間迷向訓練機」籌建工程。

由於空間迷向訓練機需使用運動平台系統來提供空間迷向之動態模擬，因此運動平台系統為空間迷向訓練機之關鍵裝備。運動平台系統所包含的裝備有六軸動感平台、旋轉軸座、操縱桿力感控制器、部份座艙操縱機構、及電子滑環。本組為爭取研發時程及採用市場現有之高效能產品，故將運動平台系統以購案方式，委由奧地利 AMST 公司製造(原購案號碼：XW90149)，其中六軸動感平台及操縱桿力感控制器由 AMST 公司向荷蘭 FOKKER 公司採購裝備，再行組裝測試。本組為祈能如期如質完成運動平台系統交運，以配合後續空間迷向訓練機之全系統整合驗證，故於購案中明訂承廠商應於合約簽署後三個月內安排舉行系統設計審查會，六個月內安排舉行系統整合審查會。以使本組能全程瞭解運動平台系統之設計、製作、及界面整合工作。

系統設計審查會亦邀請岡山醫院人員一同前往與會，雖岡院已將「航空生理訓練之空間迷向訓練機」案交由中科院模擬組研究發展，但岡院所扮演的角色不僅是買者而已，岡院人員擁有航空生理醫學方面的知識，可與中科院共同參與訓練機之開發與研製，故因此岡院人員亦扮演系統設計者的角色，這也符合中科院 CUSTOMER IN THE LOOP 的產品開發策略。

另於設計審查會後，安排至英國 SEOS 公司及 PRIMARY IMAGE GRAPHICS 公司等二處拜會。這二家廠商均為當今世界上在模擬器相關產業界中之翹楚，參訪的目的在瞭解其視效系統設計及整合，以助本組於日後之運動平台系統之接收驗證及空間迷向訓練機全系統整合驗證工作之推展。另瞭解該公司之新產品研發情況，做為本組日後專案之參考。

本次公差出國的任務及工作目標為：

1. 赴荷蘭 FOKKER 公司，瞭解 AMST 公司訂購之六軸運動平台系統及

力感控制器之規格、製造現況、交貨期程、及工程界面研討。

2. 赴奧地利 AMST 公司，執行運動平台系統購案之系統設計審查會，此次審查會主要的工作為：

(1) 審查運動平台系統設計及架構是否滿足本組設定之規格及功能。

(2) 瞭解運動平台系統設計期間所發生的任何工程界面問題。

(3) 審查AMST公司所選用的裝備規格。

(4) 審查運動平台系統即時控制軟體之架構及參數界面設計。

(5) 審查運動平台系統之硬體裝備界面與軟體程式介面。

(6) 說明由國內製作的座艙系統之結構搭接界面設計。

3. 至英國 SEOS 公司瞭解平行光顯像系統之整合驗證，以協助本組自行研發之平行光顯像系統的整合與驗證。

4. 至英國 PRIMARY IMAGE GRAPHICS 公司瞭解 PC 級影像產生器及其相關週邊配置之系統整合與驗證。

此次公差行程係由本院主導所有系統設計審查會與參訪活動，並納入岡院兩員共同配合執行，有關公差成員的工作分工說明如表一。

表一、工作分工說明

單　　位	級職	姓　名	任　務　分　配　及　說　明	備　考
一所模擬組	上校 組長	杲中興	一、負責空間迷向訓練機運動平台系統設計審查會之召開與主持。 二、審查運動平台系統設計及架構是否滿足本組設定之規格及功能。 三、研討運動平台系統設計期間所發生的任何工程界面問題。 四、拜會國外模擬器相關產品業者，增加本組業務範疇及與國外廠家之合作機會，提昇本組模擬能量。	領隊
一所模擬組	薦聘 技士	倪志文	一、參與運動平台系統設計審查會。 二、審查運動平台系統設計及架構是否滿足本組設定之規格及功能。 三、說明由國內製作的座艙系統之結構搭接界面設計。 四、蒐集運動平台系統之接收驗證與空間迷向訓練機全系統整合驗證工作之技術資料。 五、買方提供裝備(BFE)及買方提供文件(BFD)之點交。	
一所模擬組	中校 技士	楊中強	一、參與運動平台系統設計審查會。 二、審查 AMST 公司及荷蘭 FOKKER 公司所選用的裝備規格。 三、審查運動平台系統之硬體系統界面設計及軟體程式介面設計。	

單　　位	級職	姓　名	任務分配及說明	備　考
			四、AMST公司提供之技術資料點收。 五、蒐集運動平台系統之接收驗證與空間迷向訓練機全系統整合驗證工作之技術資料。	
一所模擬組	簡聘 技正	趙思本	一、參與運動平台系統設計審查會。 二、審查運動平台系統之即時控制軟體架構設計。 三、蒐集空間迷向錯覺模擬課目之相關技術資料。 四、蒐集平行光顯像系統及夜視力/夜視鏡訓練器之系統整合與驗證技術資料。	
國軍岡院	上校 主任	溫德生	共同參與空間迷向訓練機運動平台系統設計審查會。	
國軍岡院	少校 航工官	宋繼綱	共同參與空間迷向訓練機運動平台系統設計審查會。	

貳、　公差心得

此次公差主要目的是參加於 AMST 公司舉行的運動平台系統設計審查會，於行程中亦安排參訪荷蘭 FOKKER 公司先行瞭解 AMST 公司訂購之六軸運動平台系統及力感控制系統之製造現況、至英國 SEOS 公司瞭解平行光顯像系統之設計與製作、及至英國 PRIMARY IMAGE GRAPHICS 公司瞭解 PC 級影像產生器與其相關週邊配置之系統整合與驗證。另於荷蘭行程空檔時間，自行搭車前往 DELFT 大學航空工程系參觀現正進行整合之 SIMONA 模擬器。此次公差的行程表如表二所示。

表二、公差暨參訪行程表

日期	國家	公司	工作項目	備註
90.06.05	荷蘭	DELFT 大學	參觀航空工程系之 SIMONA 模擬器	參訪
90.06.06	荷蘭	FOKKER	先行瞭解 AMST 公司訂購之六軸運動平台系統及力感控制系統之製造現況	參訪
90.06.08 ｜ 90.06.12	奧地利	AMST	參加運動平台系統設計審查會	開會
90.06.14	英國	PRIMARY IMAGE GRAPHICS	瞭解 PC 級影像產生器與其相關週邊配置之系統整合與驗證	參訪
90.06.15	英國	SEOS	瞭解平行光顯像系統之設計與製作	參訪

運動平台系統設計審查會及參訪行程記要將詳細地於下列章節中說明。

2.1 運動平台系統設計審查會

本組配合國軍岡山醫院委託研究發展「航空生理訓練之空間迷向訓練機」，由於空間迷向訓練機需使用運動平台系統來提供空間迷向之動態模擬，因此運動平台系統為空間迷向訓練機之關鍵裝備。為爭取研發時程及採用市場現有之高效能產品，故將運動平台系統以購案委由奧地利 AMST 公司製造(原購案號碼：XW90149)。由於整套運動平台系統較為複雜，且需再與本組設計製作之座艙系統、教官台系統、視效投影系統、模擬主計算機系統及電力

空調系統整合，故於購案中明訂承廠商應安排兩次審查會；於合約簽署後三個月內舉行系統設計審查會，及於合約簽署後六個月內舉行系統整合審查會。本組為祈運動平台系統能如期如質完成交運，以配合後續空間迷向訓練機之全系統整合驗證，故須全程瞭解運動平台系統之設計、製作、及界面整合。

此次於 AMST 公司舉行的運動平台系統設計審查會自 90 年 6 月 8 日至 90 年 6 月 12 日止，為期三天。系統設計審查會的討論事項、會議結果、工程變更、及對本案合約影響的程度等，將於下列章節中詳細說明。

AMST 公司參與此次運動平台系統設計審查會的人員計有：董事長 RICHARD SCHIUSSLBERGER、工程部門經理 WOLFGANG TISCHER、專案經理 MANFRED KNOLZ、機械工程師 MANFRED SEEMAYER 等四人。

2.1.1 空間迷向機運動平台系統購案之範疇

空間迷向機運動平台系統購案所含蓋的裝備可分為三大部分：

(一) 载台系統：載台系統將提供搭乘者空間迷向之動態感受，載台系統可概分成旋轉軸座及六軸動感平台二大部份，其基本裝備需求為：

(1) 六軸動感平台：提供六自由度運動，包括俯仰、滾轉、偏航、上下、左右擺動、及前後擺動。

A. 六軸電動致動器及上三角平台結構；

B. 氣彈次系統；

C. 運動控制機櫃；

D. 動感法則(MOTION CUE)及控制軟體；

(2) 旋轉軸座：提供一獨立的± 360^{O} 偏航自由度，最大旋轉轉速度為每分鐘 30 轉。

A. 軸承及馬達；

B. 控制器；控制軟體；(二) 座艙操控裝置：

(1)中置駕駛桿機構(含兩組力感控制器)；

(2)方向舵踏板；

(3)油門操縱裝置；

(4)集體桿(含一組力感控制器)；

(5)座椅 — 椅背、高度、前後等均可調整。

(6)力感控制器：

A. 電馬達致動器；

B. 力感控制電腦；

C. 控制軟體；

D. 訊號放大器；

E. 電源供應器；

（三）電子滑環

(1)電力電子滑環

(2)訊號電子滑環：包含五種訊號格式；

A. 乙太網路訊號；

B. 類比/數位控制訊號；

C. 視訊訊號；

D. S 端子視訊訊號；

E. 音訊訊號；

2.1.2 運動平台系統設計審查會議題

AMST公司於運動平台系統設計審查會中所提報事項之議程共計有八項，分述如下。

2.1.2.1 工作分項計劃表及時程表檢討

AMST公司於會議中提報的工作分項計劃表及時程表詳如附件一及附件二資料所示。依據本組之專案管理經驗及本案之實際現況，本組於會議中針對此兩項工作表提出修正意見：

(1) 工作分項計劃表：

A. 增加系統功能展示之工作分項。

B. 於軟體分項中增加動感法則、力感控制、及旋轉軸座控制等三項子分項工作。

C. 於後勤支援分項的文件次分項中增加接收測試文件。

D. 於後勤支援分項的訓練課程次分項中增加教育訓練課程文件。

(2) 工作時程表：

A. 依據修訂後之工作分項計劃表，同步修正工作時程表。

B. 增加 ON SITE TEST 之工作時程。

C. 依據目前 AMST 公司之執行現況及全案交運時程延遲三週等資訊，同步修正工作時程表。並於會中決議 AMST 公司應於設計審查會後一週內，提供修正後的工作分項計劃表及工作時程表予本組。

2.1.2.2 FOKKER 636-3500 運動平台系統規格討論

經 90 年 6 月 5 日參訪荷蘭 FOKKER 公司確知其六軸運動平台的規格值與認知上存有相當大的差距，而主要的差異點有三項，且此差異將嚴重影響本案

與國內製造的座艙之設計與製造。

(1) 運動平台酬載：3500 公斤，但需扣除上三角結構體的重量 500 公斤，故對使用者而言僅剩 3000 公斤。

(2) 平台酬載之重心點位置：從上三角結構體的底部向上 1 公尺以內，但需包含上三角結構體的厚度 0.3 公尺。

(3) 平台之電源供應：任何標準的電源供應值。

本案合約中明訂平台酬載除承載本案合約所訂購的裝備外，必須提供我方額外 2500 公斤的承載，用以安裝由國內製作的座艙、平行光銀幕、及相關之電腦裝置。如照 FOKKER 公司之六軸運動平台系統的規格來看，AMST 僅剩 500 公斤的承載可用。於會議中與該公司專案經理初步估算 AMST 所負責的裝備總重量已超過 700 公斤，此將無法滿足合約中額外 2500 公斤承載的需求。另平台上三角結構體的厚度達 0.3 公尺，加上旋轉軸座所需之高度，以及將力感控制器放至於座艙下方所需的空間高度至少需有 0.5 公尺；很明顯地勢必無法滿足重心點位置從上三角結構體的底部向上 1 公尺以內的規格。當運動平台上所有裝備的質量重心點位置超過此限制值後，將嚴重地限制平台系統的動程反應，或更甚會造成平台損壞。對於平台負載不足及重心位置限制的問題，AMST 董事長 RICHARD 於會議中提出解決方法：

(1) 取消使用 FOKKER 平台的上三角結構體，由 AMST 負責重新設計與製造平台上支撐結構。

(2) 降低力感控制器放至於座艙下方所需的空間高度由 50 公分至 15 公分，並將 H MOTOR 安裝至座艙站前方之可用空間。

(3) 為配合平台以上所有裝備淨重心點降低的要求，AMST 同意整體的座艙底部結構之設計製造由他們負責，而本組需提供座艙底部結構之尺寸需求、機構搭接界面、及各項裝備安裝位置與重量等資訊予 AMST 公司。

(4) AMST 公司提供國內設計製造的座艙結構之搭接界面。

另有關於運動平台系統之電力需要，FOKKER 公司告知 AMST 公司，其運動平台系統之電力需求僅有 380~480 VAC，50~60 HZ，3Ø4W 之規格，故 AMST 需額外採購電壓轉換器因應；但此將造成全系統電力多一級的消耗及維護工作的增加；本組於會議中告知 AMST 公司運動平台系統可採用任何標準的電力供應，不需額外採購電壓轉換器。 AMST 公司將向 FOKKER 要求變更。

2.1.2.3 座艙操控裝置設計

（一）力感控制器：

(1) 已確定選用 FOKKER 公司之 H MOTOR 力感控制器。

(2) 共三組；兩組用於中置駕駛桿，一組用於集體桿。

(3) H MOTOR 力感控制器將安裝於座艙站前方的可用空間。（二）座椅機構：

(1) 同意 AMST 採用該公司原 DISO 所設計之座椅型式，並加以修改以滿足我方需求。

(2) 座椅機構之高度調整為上下 65 mm。

(3) 椅背調整角度從 0 度至 30 度，採用三段式(0°/13°/30°)手動調整。

(4) 座椅機構之前後調整行程為 600 mm，採用電動式調整。此部分為新增之需求，AMST 公司同意製造，但需增加合約價款美金 17,700 元，同時交運時程延後八週。考量本案時程已相當緊迫及 AMST 確實需新增工作項目，經雙方密集磋商，AMST 提出增加合約價款，但交運時程延後三週，且接收測試時間由原合約訂定的 45 天縮減為 40 天。我方將針對此變更，返台後依規定正式提出修約需求。（三）中置駕駛桿機構：

(1) AMST 採用該公司原 DISO 所設計之兩節式桿柄，經本組說明桿柄應為一整體之設計，AMST 同意改採用該公司另一型駕駛桿(PC-7)

的設計。

(2) 本組應儘速提供 F-5E 駕駛桿頭及相對應的接頭予 AMST 公司。

(3) AMST 公司應同步修改中置駕駛桿機構之設計藍圖。（四）油門操縱裝置：

(1) AMST 採用 F-16 單手柄油門操縱裝置之仿真件。但無 F-16 單油門手柄之外觀圖及安裝圖。

(2) 本組於會中已將 F-16 單手柄油門操縱裝置之相關照片交駐廠人員，提供 AMST 於設計時參用。（五）方向舵踏板：

(1) 同意 AMST 採用原 DISO 使用的方向舵踏板。

(2) 踏板機構依國人腳型加裝前靠邊。

（六）集提桿：

(1) 採用 AH-1W 集提桿裝置之仿真件。

(2) 目前 AMST 尚無設計進度，故於會議中並沒有做設計提報。

2.1.2.4 電子滑環規格討論與確認

電子滑環截自系統設計審查會為止，AMST 尚無設計進度且尚未訂購。於會議中本組強烈表達此項設計工作進度嚴重落後，將會影響全案交運時程。並要求 AMST 於兩週內完成規格制定及裝備訂購的工作。

AMST 專案經理於會中表達對電子滑環規格提出疑慮，認為我方所開出之規格值太高，市場上不可能有此類產品。本組即於會中提出美加地區有可滿足此規格值的廠家產品，並當場出示相關產品資料，其專案經理便不再辯解。我方請其說明其訪商所遇到的困難處在那裡，其便將無法滿足合約需求的規格指出，包括：

(1) 內徑 4 吋之通氣孔；

(2) 電子滑環之總長度；

(3) 訊號電子滑環之頻寬值；

(4) 電子滑環之壽期；

(5) 電子滑環之總外徑；

於會中本組仍強烈表達希望能依照合約中訂定的規格值儘速訪商決定，AMST 董事長 RICHARD 答應於 6 月 13 日親自帶隊至德國 SAF 公司將規格敲定，並簽約訂購。

AMST 如期於 6 月 13 日由董事長帶隊至德國 SAF 公司討論電子滑環規格，並於當晚聯絡遠在英國參訪的我們，並電傳在德國 SAF 公司所討論的結論，電傳資料如附件三所示。因本案所定之規格屬高檔產品，在設計製造的時程上將會很長，且將使電子滑環的總長度及外徑值變大，恐將影響到運動平台之動程。AMST 希望雙方能在規格值上相互讓步，以便全案能順利進行。於 6 月 13 日當晚，我們即於英國連夜討論出全案需求的最低可接受規格值，並刪減部分備用環數，以顧及本案交運時程、及電子滑環與運動平台動程之間的干涉現象。於 6 月 14 日一早即電傳(詳如附件四)告知 AMST 董事長電子滑環最後的需求規格，AMST 感謝我方的快速回應，並立即向 SAF 公司簽定訂購合約。雖然我方在電子滑環的規格上做了需求降低的讓步，但我方亦要求 AMST 公司，此部份因需求變更，應該減少合約價款，AMST 公司同意此提議。這部分的變更將和在座椅機構新增需求一併提出修約。

經過雙方於設計審查會之後的密集聯繫及討論，終於底定電子滑環最終之規格為：

(1) 通氣孔之內徑：100 mm；

(2) 電子滑環之總長度＜600 mm；訊號電子滑環之環數及頻寬值：

(4) 電力電子滑環：10 環(4 組)；

(5) 訊號電子滑環：

A. 乙太網路訊號電子滑環： 25 環(3 組)；頻寬值為 100 Mbps；

B. 類比/數位訊號電子滑環： 13 環(6 組)；頻寬值為 10 MHz；

C. 攝影機 S 端子訊號電子滑環： 此項刪除；

D. 視訊訊號電子滑環： 3 環(1 組)；頻寬值為 15 MHz；

E. 音訊訊號電子滑環： 5 環(2 組)；頻寬值為 100 KHz；

(6) 電子滑環之壽期：10 百萬轉；

(7) 電子滑環之總外徑＜250 mm

2.1.2.5 旋轉軸座規格討論

旋轉軸座截自系統設計審查會為止，AMST 尚無設計進度且尚未訂購。於會議中本組強烈表達此項設計工作進度嚴重落後，將會影響全案交運時程。並要求 AMST 於兩週內完成規格制定及裝備訂購的工作。因旋轉軸座上需承載座艙、平行光銀幕、及相關電腦設備，且座艙底部結構將由 AMST 公司負責設計製造，故於旋轉軸座及驅動馬達之規格選用時，需清楚知道座艙中各項裝備的重量及安裝位置，以便估算 Izz 軸之轉動慣量。本組將於設計審查會後儘速提供此方面的資訊予 AMST 公司，以協助其儘早選定旋轉軸座軸承及驅動馬達。為考量降低全系統之網路傳輸量、降低系統複雜度及不穩定性、及提高系統維護度，於設計審查會中向 AMST 公司提議將旋轉軸座之控制器及控制軟體併入六軸平台運動控制處理器中作解耦控制，以旋轉軸座與六軸運動平台系統間運動的解耦控制，即兩者間呈相互獨立的運動模式。AMST 公司同意此項提議。另要求於旋轉軸座中增加電磁煞車裝置，以提昇旋轉軸座的可控制性，AMST 同意。

2.1.2.6 後勤支援

在後勤支援方面，本組於設計審查會中提出三項議題討論，分別為：

(一) 教育訓練課程：

(1) 於參訪荷蘭 FOKKER 公司時，得知 AMST 僅向其購買力感控制系統之訓練課程，但不是本組所希望的課程，因本組已有此能量。本

組所希望的課程為六軸運動平台系統相關軟硬體之操作維護課程。

(2) 本組已於本案合約明訂所要的訓練課程為六軸運動平台系統的相關訓練，包括系統硬體界面、維護、調校、偵錯與故障隔離、及軟體操作程序。

(3) 於會議中本組強烈表達 AMST 公司應向 FOKKER 公司購買六軸運動平台系統的訓練課程，並於該公司人員前往受訓時，本組派駐該公司之駐廠工程師亦需一同前往受訓。

(4) 經 AMST 公司立即與 FOKKER 公司連絡，同意變更為六軸運動平台系統的訓練課程，並預定七月中旬派人至 FOKKER 公司接受六軸運動平台系統(三天)及力感控制系統(一天)的訓練課程。此訓練課程亦將於全案在國內完成系統接收測試後兩週內實施，參訓人員至少八員，訓練課程時數至少八十小時，授課教師由 AMST 公司工程人員擔任。**(二) 後勤零備件：**

於審查會中請 AMST 公司就全案合約所採購的各項裝備之平均故障時間(MTBF)及獲得時程(LEAD TIME)作分析，提供本組零備件建議清單。

(三) 品保驗證：

於審查會中要求 AMST 公司增加品保人員加入本案，以完整執行本案系統功能的驗證與測試，確保品質要求。AMST 公司同意此作法。

2.1.2.7 裝備交運時程

原本購案合約中訂定之裝備交運時程為合約簽定後七個月內，即預定 90 年 10 月 15 日前交運至本組。因此 AMST 公司原預定 90 年 9 月 28 日完成裝備裝運工作。

因於座椅機構新增前後滑動 600 MM 之設計需求，AMST 公司要求交貨時程延遲三週，即 90 年 11 月 5 日前交運至本組。AMST 公司預定 90 年 10 月 22 日完成裝備裝運工作。而系統交運後之接收測試時間，由原合約訂定的 45

天縮減為 40 天。有關裝備交運時程變動的差異整理如下表所示。

	原合約訂定日期	設計審查會 AMST 提議日期
交運至台中一所	90 年 10 月 15 日	90 年 11 月 5 日
接收測試(ATP)期程	90 年 10 月 16 日至 90 年 11 月 30 日 (45 天)	90 年 11 月 06 日至 90 年 12 月 15 日 (40 天)
	運動平台系統交運時程延遲三週 空間迷向機全案整合驗證時程預計延遲二週	

2.1.2.8 會議記錄簽署

此次運動平台系統設計審查會之會議記錄詳如附件五頁所示。於會議記錄中有 28 項工作事項，其中 26 項屬於 AMST 公司應執行或需澄清的事項，另 2 項屬於本組應執行。

此會議記錄及後續執行結果將納入全案合約管理中。

2.1.3 運動平台系統工程變更

此次運動平台系統設計審查會有關工程變更部分共計有四項，將分別就原購案合約需求、需求變更說明、及對合約的影響等三方面說明如下。

（一）座椅機構：

A. 原購案需求：

(1) 座椅高度調整配合不同身高(155~195 公分)；

(2) 椅背調整角度從 13 度至 30 度；

B. 需求變更：

(1) 座椅高度調整為上下 65 mm；

(2) 椅背調整角度從 0 度至 30 度，採用三段式(0°/13°/30°)手動調整；

(3) 新增座椅機構之前後調整，調整行程為 600 mm，採用電動式調整；

C. 合約影響：

(1) 合約價款增加美金 17,700 元。

(2) 交貨時程延遲三週 (原需延遲八週)。而系統交運後之接收測試時間，由原合約訂定的 45 天縮減為 40 天。

(3) 上述變更事項需修訂購案之合約內容。

（二）電子滑環：

A. 原購案需求：

(1) 電力電子滑環：25 環(8 組)；

(2) 訊號電子滑環之環數及頻寬值：

A. 乙太網路訊號電子滑環： 25 環(3 組)；頻寬值為 100 Mbps。

B. 類比/數位訊號電子滑環： 24 環(12 組)；頻寬值為 100 MHz。

C. 攝影機 S 端子訊號電子滑環： 5 環(1 組)；頻寬值為 150 MHz。

D. 視訊訊號電子滑環： 2 環(1 組)；頻寬值為 150 MHz。

E. 音訊訊號電子滑環： 6 環(3 組)；頻寬值為 100 KHz。

B. 需求變更：

取消備用電子環數及降低訊號頻寬，保留最基本之系統規格需求。

(1) 電力電子滑環：10 環(4 組)；

(2) 訊號電子滑環：

A. 乙太網路訊號電子滑環： 25 環(3 組)；頻寬值為 100 Mbps。

B. 類比/數位訊號電子滑環： 13 環(6 組)；頻寬值為 10 MHz。

C. 攝影機 S 端子訊號電子滑環： 刪除；

D. 視訊訊號電子滑環： 3 環(1 組)；頻寬值為 15 MHz。

E. 音訊訊號電子滑環： 5 環(2 組)；頻寬值為 100 KHz。

C. 合約影響：

(1) 因需求項目減少，可要求合約價款減少。

(2) 上述規格變更事項，需修訂購案之合約內容。**(三)力感控制器：**

A. 原購案需求：

原合約中訂定之規格值，係指定 FOKKER 公司之 M MOTOR 力感控制系統。

B. 需求變更：

(1) AMST 採用比 M MOTOR 功能更高一級之 H MOTOR 力感控制系統。

(2) H MOTOR 因體積較大，為配合平台以上所有裝備淨重心點降低的要求，H MOTOR 力感控制系統將安裝於座艙站內。

C. 合約影響：

此分項無需修訂購案之合約內容。

(四)座艙底部結構：

A. 原購案需求：

原合約中並未明定座艙底部結構由 AMST 公司負責設計及製造，AMST 僅需設計承載座艙操縱裝置之承座，再與由國內設計製造的座艙底部結構與其承座銜接。

B. 需求變更：

為配合平台以上所有裝備淨重心點降低的要求，AMST 同意整體座艙底部結構之設計製造由他們負責，而本組需提供座艙底部結構之尺寸、機構搭接界面、及各項裝備安裝位置與重量等資訊予 AMST。

C. 合約影響：

此分項無需修訂購案之合約內容。

2.1.4 文件資料

此次運動平台系統設計審查會所攜回的文件資料清單整理如表三，詳細的文件資料於附錄所示。

表三、 文件資料清單

附件編號	文件編號	文件名稱
一		運動平台系統案之工作分項計劃表
二		運動平台系統案之工作時程表
三		有關電子滑環規格，AMST 董事長之來函
四		有關電子滑環規格，我方回覆之電傳
五		運動平台系統設計審查會之會議記錄
六	MAMS_DSO_FRD	FACILITY REQUIREMENTS DOCUMENT FOR E-CUE 636-3500 MOTION SYSTEM
七	MAMS_DSO_ICD	INTERFACE CONTROL DOCUMENT E-CUE 636-3500 MOTION SYSTEM FOR AMST
八	MAMS_DSO_SDR	SYSTEM DESIGN REPORT E-CUE 636-3500 MOTION SYSTEM FOR AMST
九		FCS MOTION CONTROL SOFTWARE; FCS MOTION CUEING ALGORITHM; FCSEXPOLRER;
十	A25018-03123-81-000-APD	CENTRAL CONTROL COLUMN DRAWING
十一	A25018-03123-20-000-APD	THROTTLE BOX DRAWING
十二	A25018-03123-01-000-APD	RUDDER PEDALS DRAWING
十三	A25018-03123-00-000-APD	SEAT ASSEMBLY DRAWING

2.2 參訪記要

2.2.1 參訪荷蘭 FOKKER 公司

位於荷蘭史基浦機場旁之 FOKKER CONTROL SYSTEM 公司，係由 FOKKER 飛機製造公司獨立出來。自 1970 年代起從事有關訓模器相關裝備的生產製造，主要產品為動感平台系統及力感控制系統，目前相關產品廣泛運用於飛機、火車、及卡車等模擬器上。FCS 動感平台研發起步較晚，但他們躍過液壓動力源系統而主攻開發電馬達致動的動感平台，所以相較於 MOOG，HYDRAUDYNE S&E…等資深專業廠，雖是後起新秀卻也能與這些動感平台大廠在電馬達致動平台性能上一較長短。

運動平台系統購案的主承製商為奧地利 AMST 公司，其中六軸運動平台及操縱桿之力感控制系統等兩項裝備是由 AMST 公司向荷蘭 FOKKER CONTROL SYSTEM 公司採購。此次前往 FOKKER CONTROL SYSTEM 公司主要的目的在瞭解 AMST 公司向其訂購之六軸運動平台系統及力感控制系統之製造現況，並與該公司工程人員直接面對面研討本組關切的六軸電動平台系統相關工程問題，包括：

1. 交運至 AMST 公司之時程；
2. 運動平台之酬載；
3. 運動平台之重心位置；
4. 運動平台安裝之地樁錨點；
5. 運動平台之電力供應；
6. 運動平台之 MOTION CUE 軟體需求；
7. AMST 公司購買之教育訓練課程；
8. 力感控制系統之機型及控制模；

經長達近四小時的會議，與 FOKKER 模擬事業部業務經理 STEVEN

STREEFKERK、專案經理 WOUTER BIEMANS、及相關工程人員，針對以上八點本組關切的問題做深入探討，得到澄清如下：

(1) 交運至 AMST 公司之時程：FOKKER 公司預計 6 月 14 日交運平台之上三角結構體至 AMST，提供其先期整合工作，8 月 14 日完成六軸運動平台系統及力感控制器之交運。FOKKER 公司所提供詳細的交運時程表如附件一所示。運動平台之酬載：AMST 公司所訂購的六軸電動平台系統之型號為 636-3500，其酬載重量為 3500 公斤，但需包括 FOKKER 公司提供之上三角平台結構的 500 公斤，因此使用者僅有 3000 公斤的酬載重量可使用，而非 3500 公斤的酬載重量。

(3) 運動平台之重心位置：636-3500 六軸電動平台系統之重心位置限定在從上三角結構體的底部向上 1 公尺以內，但需包含上三角結構體的厚度 0.3 公尺。此點將影響到平台之上的座艙外型及內部裝備配置等設計。

(4) 運動平台安裝之地樁錨點：原希望能直接從 FOKKER 公司取得運動平台安裝之地樁錨點尺寸圖，以便於廠房興建時先行安裝地樁螺栓。但 FOKKER 工程人員告知可不需先行安裝地樁螺栓，待運動平台安裝前一週，再行施工安裝化學地樁螺栓即可，而且精準性也較高。

(5) 運動平台之電力供應：FOKKER 公司宣稱 636-3500 六軸電動平台系統為生產型之產品，故電力需求僅有 380~480 VAC，50~60 HZ，3Φ4W 之規格，無法修改成其他型式的電源值。此種說法令人生疑，因本組與 FOKKER 無合約關係，故無法要求其變更設計，將於系統設計審查會時向 AMST 提出。運動平台之 MOTION CUE 控制軟體需求：本組於會談中強烈希望 FOKKER 能隨系統提供 LEVEL-3 之 MOTION CUE 控制軟體，以使運動平台獲得較佳的動態性能；另希望將 MOTION CUE 之模擬模式設定為直昇機模式。FOKKER 同意以上兩項要求。

(7) 教育訓練課程：據 FOKKER 告知 AMST 僅購買力感控制系統之教育

訓練課程，而未購買六軸電動平台系統相關之訓練課程；此項訊息將於系統設計審查會時向 AMST 提出嚴正關切。

(8) 力感控制系統之機型及控制模：據 FOKKER 告知 AMST 向其購買 H MOTOR 型式之力感控制系統，而體積較小的 M MOTOR 型式；目前 FOKKER 已完成製造工作，待交貨。另於會談中亦提出力感控制模式需設定為直昇機模式(因本組已有定翼機力感操作模式的相關程式與數據)。

於研討會議之後，FOKKER 公司之專案經理亦帶我們參觀該公司的生產區及現正生產的裝備，茲將重點摘要如下：

1. 參觀結構試驗棚廠，內容包括力感系統、動感平台的研發製造過程及正配合歐洲大汽車廠開發汽車雙手駕駛桿系統。
2. 參觀 FOKKER 公司新建案之空中巴士－超級古比(800 人客機)運動平台系統，在平台上將承載七十公頓之中段機身艙體，艙體內有實體客機座椅及客艙相關次系統，平台致動器採用液壓驅動，此案為目前世界上最大的動感平台系統。
3. 參觀原 FOKKER 公司飛機維修棚廠，在該廠區內驚見第二次世界大戰美軍使用之轟炸機，並有機會進入該機艙，一探艙內配置，此為相當難得的經驗。

2.2.2 荷蘭 DELFT 大學航空工程系

於 6 月 5 日抵達荷蘭阿姆斯特丹且進住旅館後，一行人便搭車前往 DELFT 大學航空工程系，參觀由該系一系列與航空研究相關的設備，尤其是目前仍在籌建的 SIMONA(SIMULATION, MOTION, AND NAVIGATION)模擬器。原本此行並未在預劃的公差行程中，但 SIMONA 模擬器與本案製造的迷向訓練機在架構上有許多相似的地方，因此引發前往參訪的動機。

SIMONA 模擬器始建於 1992 年，其結合該校航空工程、機械工程、電機工

程、資訊工程、及航運技術共同開發此設備。SIMONA 模擬器為一開放式的設備，設置的目的在提供全世界各模擬研究單位及模擬生產公司做航空工程研究領域之用。主要的研究方向為安全且經濟有效的航運。其將提供給目前及未來運輸工具開發的一個模擬環境，這些運輸工具包含客/貨機、太空船、旋翼機、及自動車等；亦可用於人員運動感知的基礎研究。

SIMONA 模擬器為六軸液壓驅動之動感平台系統(為荷蘭 HYDRAUDYNE 公司的產品)，座艙採用質輕堅固的結構設計，並直接與六軸液壓驅動器銜接，故取消了上三角平台結構，且降低平台上的運動質心位置；另採用美國 EVANS & SUTHERLAND 公司之視效影像產生器，及英國 SEOS 公司之 PANORAMA 平行光顯像系統；軟體程式則由該校自行開發。

參訪行程先由航空工程系系主任及負責 SIMONA 開發的分項負責人做簡要的系統提報，於簡報完後，帶我們至模擬器教室參觀並詳細解說正進行組裝的 SIMONA 模擬器，同時亦同意我們可任意拍照，此為相當好的機會，整個參觀過程中，將一些結構設計方式、設計巧思、裝備擺置、甚至廠房外觀均拍照留存，無一遺漏，這些照片可作為本組在設計運動平台模擬器之參考。

參觀完 SIMONA 模擬器後，接著帶我參觀該系的實驗室及自行開發的設備，包括：航運管理系統、座艙人機操控界面站、座艙 4D 空中隧道顯示系統、及無重力飛行研究。

參觀完 DELFT 大學航空工程系，有幾點心得可值得參考：

(1) 該系現正與政府或企業研究機構有許多研究計劃在進行中，確切做到產官學合一的境界。

(2) 該校對學生的教育方式，除書籍上的理論教授外，另要求學生能實際利用學校設備做與產業界相關的研究，且不限本系以外的學生使用，可說做到了結合產業需求至學習中及設備共用共享。

(3) 該系實驗室中部分的研究設備是由學校教授帶領學生研發出來，其中可見到許多巧思的設計理念，例如：SIMONA 模擬器之人員登機梯不採用傳統的舉昇梯或固定梯的設計，而採用側向移動式的設

計，當人員登機需移動時，氣墊先充氣，將梯柱頂起，接著致動器再將梯子向側面移動，將其移離運動平台之運動區域範圍。

(4) 該系放置 SIMONA 模擬器的廠房外觀相當現代化，廠房一面採用玻璃帷幕的設計，使室內的光線充足而明亮，且室內空間單純，未見突的樑柱；不似一般傳統封閉式的廠房。

2.2.3 英國 PRIMARY IMAGE GRAPHICS 公司

PRIMARY IMAGE GRAPHICS 公司的主要業務是 PC 級影像產生器 (IMAGE GENERATOR)，它的前身是 AKEBIA 公司 (成立於 1978 年)，1989 年改名為 PRIMARY IMAGE，1998 年分割成兩個子公司，一個做 GRAPHICS，一個做 VISION SYSTEM，我們此行參觀的是做 GRAPHICS 的子公司，它約有 50 名員工。

PRIMARY IMAGE GRAPHICS 公司的主要產品包括：

1. RENAISSANCE：尚在發展中，目標涵蓋低階到高階的應用，依價格高低而有不同的性能表現，它是一個完整的影像產生器系統。
2. BARRACUDA：3D 繪圖卡，具備獨立的 CPU 及 MEMORY，其效能不受 PC 的頻寬限制。
3. TEMPEST：視效程式介面軟體，支援 PRIMARY IMAGE、OPENGL、DIRECT3D、GLIDE 等繪圖語言，使用 PRIMARY IMAGE 會得到最大的效能。
4. P10+：3D 繪圖卡，以 2D 的真實照片為背景，加上 3D 的移動模型，適用於定點武器的模擬，如刺針飛彈、防空火砲等，因為使用真實照片為背景，逼真度非常好。
5. CRUNCHER：幾何圖形處理器，加在 BARRACUDA 前面，以取代 BARRACUDA 的幾何計算功能，使 BARRACUDA 全力用於圖點計算，而 CRUNCHER 可處理更多的 POLYGON。

6. TOW TRAINER：TOW MISSILE 發射訓練器，以提高學員的瞄準能力。

7. SENSORSIM：感測器模擬系統，可模擬熱影像、紅外線感測器。

PRIMARY IMAGE 公司於現場做了一個 3 頻道影像產生器的展示，以一台 PC 裝三片 BARRACUDA 繪圖卡，之間用一段排線將 GENLOCK 接在一起，使三個畫面能夠同步，然後執行一個直昇機對地攻擊的場景，畫面更新速率為 30HZ，解析度 1024X768，結果畫面的移動十分流暢，發射飛彈時，其尾焰會對地面產生局部的照明效果，如同照明彈一樣。另外有一個船在海上航行的場景，雪花紛紛落下，十分逼真，原來是用貼圖方式做的，使用的 POLYGON 不多。

與 PRIMARY IMAGE 公司談到軟硬體的價格時，其銷售經理 MARTIN PINCOCK 先生提供了一些資訊，硬體部分，一片 BARRACUDA 繪圖卡約需 10000 美元，軟體部分，TEMPEST 發展系統一套是 3500 美元，TEMPEST 的 RUN TIME LICENSE 是一個 CHANNEL 350 美元。

我們希望能採購一套 PRIMARY IMAGE 的影像產生器做為先期的研究評估，若能符合我方的需求，將再繼續採購，台灣本身是 PC 王國，因此我們希望只購買 PRIMARY IMAGE 的繪圖卡及軟體，PC 由我方自己準備。MARTIN PINCOCK 先生建議第一套完全購自 PRIMARY IMAGE，以確保系統正常運作，我方可利用這一套做評估，以及尋找國內適合搭配的 PC 主機，後續則只需採購繪圖卡及軟體授權即可。

最後我們談到視效資料庫的製作，MARTIN PINCOCK 先生為我們做了詳細的分析。目前業界的視效資料庫標準是「OPENFLIGHT FORMAT」，各家公司會提供一個轉換程式，將 OPENFLIGHT 轉成各家公司自己的特殊格式以供硬體使用，如此不必發展自己的 MODELING TOOL，只要用 MULTIGEN 來構建 OPENFLIGHT 視效資料庫即可。但是 MULTIGEN 並不是一個容易上手的軟體，需要較長的學習時間，而另外一種動畫軟體 3D STUDIO MAX，容易學而且同樣是用來建 3D 場景，因此有人便寫了一個 PLUG-IN 植入 3D

STUDIO MAX 內，使它能夠將資料以 OPENFLIGHT 的格式存出來，如此便能用 3D STUDIO MAX 來構建 OPENFLIGHT 視效資料庫。但是 3D STUDIO MAX 與 MULTIGEN 在原始設計理念上是不同的，例如 3D STUDIO MAX 並沒有 LEVEL OF DETAIL 的觀念。MARTIN PINCOCK 先生認為新版的 3D STUDIO MAX 將會有 LEVEL OF DETAIL，但是我們認為 3D STUDIO MAX 無法完全取代 MULTIGEN，某些部分還是得靠 MULTIGEN 來完成。

PRIMARY IMAGE 在 OPENFLIGHT 出現以前，就已經定義了一套自己的視效資料庫格式 SDA，以 AUTOCAD 做為它的構建工具，使用起來並不方便。OPENFLIGHT 出現之後，PRIMARY IMAGE 提供了一個轉換程式將 OPENFLIGHT 轉成 SDA，它並不直接拿 OPENFLIGHT 來用。

綜合此次參訪心得，有以下幾點結論：

1. PRIMARY IMAGE 公司的產品確實很不錯，與 E&S 等公司比較起來，其效能價格比非常有競爭力，未來在新的模擬器中可考慮採用。
2. PRIMARY IMAGE 的 BARRACUDA 繪圖卡採用 3DFX 的 WOODOO 晶片，兩年前 WOODOO 晶片曾是 PC 繪圖卡的當紅炸子雞，現在已經被 NVIDIA 的 GEFORCE2 晶片取代，PRIMARY IMAGE 正在與 NVIDIA 談合作事宜，從這件事我們了解到 PC 技術進步很快，PC 級影像產生器將是未來的發展方向。
3. 視效資料庫對模擬器的發展一直是個問題，傳統大型影像產生器的視效資料庫都是封閉式的，無法互相交換使用，因此每次更換新的影像產生器系統，就必須重新建一次視效資料庫。PC 級影像產生器則已經出現一個共同的標準，OPENFLIGHT，這個標準日漸普及，也逐漸被一些傳統大型影像產生器採用，我們未來應該也朝這個方向來走。
4. 有些傳統大型影像產生器的公司開始將 PC 的技術應用到他們的產品上，一方面是希望降低成本，另一方面是 PC 的技術進步太快，如此才能維持競爭力。

2.2.4 英國 SEOS 公司

SEOS 公司的業務是生產模擬器的視效顯示系統，主要的產品包括：

1. PANORAMA 雙座平行光顯示系統
2. PRODAS 正投影弧形銀幕顯示系統
3. MIDAS 模組式平行光顯示系統
4. LUCID 背投影環場顯示系統
5. MARKSMAN 目標機影像投射器
6. MERCATOR 影像變形補償系統
7. DIGIBLEND 電子式影像邊緣融合系統
8. OPTIBLEND 光學式影像邊緣融合系統

PANORAMA 雙座平行光顯示系統是 SEOS 公司最重要的主力產品，大多應用於民航機的模擬器，亦是我們此行最主要的參觀目標，SEOS 公司的市場經理 BARRY SWAINSTON 先生帶我們參觀工廠內正在加工的成品及半成品，有一個 7 呎的成品正在做反射鏡面的成形，另外一個 11 呎的半成品已完成主結構，尚未覆蓋反射鏡面，另外還看到弧形背投式銀幕，其材質呈灰色半透明，內面比較光滑而外表比較粗糙。雖然只看了 20 分鐘，但是已經讓我們了解到許多 PANORAMA 的細節，對於迷向機平行光顯示系統的製作有很大的幫助。

MARKSMAN 目標機影像投射器是我們想要了解的另一個重點，它主要是應用在球形模擬器的目標機顯示上，可提供比背景影像更清晰的解析度，在空戰模擬上十分重要。MARKSMAN 內部有一片 PRIMARY IMAGE 的繪圖卡，可自行繪製目標機影像，不必再外接影像訊號。在一個球形模擬器內最多可架設四部 MARKSMAN，小型的球形模擬器能架設的數量更少。由於時間有限，現場未能看到 MARKSMAN 的實體，相當可惜。

影像變形補償一直是弧形／球形顯示系統所需克服的問題，早期只有高階的影像產生器具備變形補償功能，當影像產生器逐漸走向 PC 化之後，變形補償的功能開始轉移到投影器上，但是最彈性的做法是將變形補償獨立在影像產生器與投影器之間，如此影像產生器與投影器將有更大的選擇空間。MERCATOR 正是這種產品，它是一片安裝在 PC 內的電路板，將輸入影像訊號數位化，做變形補償，再轉換成影像訊號輸出。MERCATOR 一般是搭配系統一起出售，當我們詢問能否單獨出售時，SEOS 公司市場經理表示可以考慮。

影像邊緣融合亦是我們有興趣的部分，但因現場並無實體，我們無法看到實際融合的效果，SEOS 公司市場經理僅能就我們的問題做口頭上的回答。

綜合此次參訪心得，有以下幾點結論：

1. PANAROMA 雙座平行光顯示系統是我們此行最想了解的東西，它的最大尺寸為半徑 11 呎，最小尺寸為半徑 7 呎，再小就不能用於雙座，航生案的迷向機是單座的，因此可以用比 7 呎更小的尺寸。
2. 11 呎的 PANAROMA 可以提供 60° 的垂直視角，220° 的水平視角，使用五部投影器；9 呎的 PANAROMA 可以提供 45° 的垂直視角，225° 的水平視角，使用五部投影器；7 呎的 PANAROMA 可以提供 45° 的垂直視角，180° 的水平視角，使用三部投影器。
3. 主體結構是以玻璃纖維做外殼，中間黏貼兩層硬質泡棉，內面再貼一層玻璃纖維。底座是用鋁板包覆玻璃纖維，底座與主體結構之間是以螺絲鎖固。
4. 左右兩側壓條寬約 3 公分，厚約 4 公分，彎曲成圓弧形，材質近似白色硬塑膠。作為反射鏡面的鍍鋁 MYLOR 是捲成一圓筒，寬度約四～五公尺，國內能找到的鍍鋁 MYLOR 只有 1.8 公尺寬，因此 SEOS 所用的鍍鋁 MYLOR 應是特別訂製的。
5. 反射鏡面成形時要連續抽氣 3～5 天，以形成永久變形。使用時抽氣機是 24 小時連續運轉的，即使關機也要讓抽氣機繼續運轉，以維持

反射鏡面的形狀，如果常常改變鏡面的形狀，容易使表面的鍍鋁層脫落。因此迷相機選擇抽氣機時需考慮長時間運轉的需求。

6. 反射鏡面成形時要維持一定的壓力差，但是實際上並不測量壓力差，而是測量 MYLOR 彎曲的深度，就如同圓上兩點所截出的弦與弧，要量測的是弦與弧之間的距離，控制弦與弧之間的距離就能調整弧的曲率。這個方法的先決條件是反射鏡面必須是圓弧的一部分。調整鏡面只能拉 MYLOR 的上下兩側，也就是調整 MYLOR 的張力，因此並不能單獨調整上半段或下半段的形狀，是否需要在低壓腔內裝精確的肋條還要再檢討。

參、 效益分析

此次參加設計審查會及參訪主要獲致下列效益:

(1) 與運動平台系統承製商奧地利 AMST 公司面對面研討系統設計規格、及與國內製作裝備間的界面設計，並於會中指示全案設計的關鍵處及 AMST 公司在設計上的缺失處，雙方在密集的討論後，也得到明確的解決方案。且雙方也具要讓本案能如期如質完成的共識。

(2) 在審查會期間，對於系統規格定義需要澄清之處，我方逐項的說明、並和 AMST 人員討論，使得 AMST 對於我方的需求更加清楚，可以避免因認知誤差而造成設計錯誤。

(3) 本院對模擬器的籌建，一直秉持「CUSTOMER IN THE LOOP」的理念，因此本次除了本院的工程人員外，並邀請客戶(國軍岡山醫院)兩位航空生理訓練方面之專家共同參與設計審查會，兩位專家學有專精，不僅提出許多從實際訓練上的寶貴意見，並且協助我方向 AMST 爭取新增功能項目，圓滿達成任務。

(4) 從 FOKKER 及 SEOS 的發展過程可以了解，「精專」是一個公司生存發展之道。對於非大量生產的產品，如何尋找利基市場，作市場區隔，是公司重要的策略。本院之產品特性亦是屬非大量生產，這兩家公司的發展策略應值得我們參考。

(5) PRIMARY IMAGE 公司的產品確實很不錯，與傳統的大型主機如 E&S 等公司比較起來，其效能價格比非常有競爭力，這對佔模擬器成本幾乎達一半的視效主機，是一項重大之發展。藉由此次的參訪，我們對於 PC 影像產生器的架構、性能、及應用範圍等，均有深刻了解，並透過工程討論，對於本組自行開發中的 PC 級影像處理器，在若干的關鍵技術得到發展之方向；同時更強化未來在模擬器視效分系統的開發及選用之能量。

（6）SEOS的PANORAMA 雙座平行光顯示系統是SEOS公司最重要的主力產品，大多應用於民航機的模擬器，亦是我們對該公司最主要的參觀目標。團員對於此項產品均非常深入的觀察，並適時提出問題，讓我們了解到許多 PANORAMA 的細節，對於迷向機平行光顯示系統的製作有很大的幫助。

（7）因本組之前均無PC級影像產生器及平行光顯像系統之性能驗證的相關技術，及運用此兩項技術於模擬器之全系統整合經驗。藉由此次前往英國 SEOS 公司詳細瞭解平行光顯像系統之設計與驗證方式，及至英國 PRIMARY IMAGE GRAPHICS 公司瞭解 PC 級影像產生器及其相關週邊配置之性能驗證。有助本組完成開發 PC 級影像產生器及平行光顯像系統此兩項技術，及日後空間迷向訓練機全系統整合驗證工作之推展。

（8）此次參訪的公司中，如 FOKKER、SEOS、PRIMARY IMAGE 均是在模擬產業各別領域的領導廠商。透過參訪，不僅了解其產品的特性及一些設計上的訣竅，同時也更這些公司建立聯絡的管道，對於本院未來即將進行新的模擬器產製案，各項分系統之選擇、採購及設計上均有極大之助益。

肆、 國外工作日程表

本次國外公差的期間為 90 年 06 月 04 日至 06 月 17 日，共計 14 天。每日工作行程表如下所示：

日 期	星期	公差地點		工作項目	備考
90.06.04	一			中正機場搭機前往阿姆斯特丹。	
90.06.05	二	荷蘭	阿姆斯特丹	1. 09:35 抵達阿姆斯特丹史基浦機場 2. 14:00 到達 DELFT 大學航空工程系，參觀 SIMONA 模擬器。	夜宿阿姆斯特丹
90.06.06	三	荷蘭	阿姆斯特丹	1. 前往 FOKKER 公司研討動感平台系統及力感控制系統。 2. 參觀 FOKKER 公司現生產之各項產品。	夜宿阿姆斯特丹
90.06.07	四	奧地利	薩爾斯堡	由阿姆斯特丹史基浦機場搭機前往奧地利薩爾斯堡。	夜宿薩爾斯堡
90.06.08	五	奧地利	薩爾斯堡	前往 AMST 公司參加運動平台系統設計審查會，審查會主要的工作為： 1. 審查運動平台系統設計及架構是否滿足本組設定之規格及功能。 2. 瞭解運動平台系統設計期間所發生的任何工程界面問題。 3. 審查 AMST 公司及荷蘭 FOKKER 公司所選用的裝備規格。 4. 審查運動平台系統即時控制軟體之架構及	夜宿薩爾斯堡

日　期	星期	公差地點		工作項目	備考
				參數界面設計。	
90.06.09	六	奧地利	薩爾斯堡	運動平台系統設計審查會資料整理，及內部工程問題研討。	夜　宿 薩爾斯堡
90.06.10	日	奧地利	薩爾斯堡	運動平台系統設計審查會資料整理，及內部工程問題研討。	夜　宿 薩爾斯堡
90.06.11	一	奧地利	薩爾斯堡	前往 AMST 公司參加運動平台系統設計審查會，審查會主要的工作為： 1. 審查運動平台系統之硬體裝備界面與軟體程式介面。 2. 說明由國內製作的座艙系統之結構搭接界面設計。 3. BFE 及 BFD 點交。	夜　宿 薩爾斯堡
90.06.12	二	奧地利	薩爾斯堡	前往 AMST 公司參加運動平台系統設計審查會，審查會主要的工作為： 1. 蒐集空間迷向錯覺課目等技術資料。 2. 工程界面問題研討。 3. 會議記錄核對及簽署。 4. 技術文件點收。	夜　宿 薩爾斯堡
90.06.13	三	英國	倫敦	由奧地利薩爾斯堡搭機前往英國倫敦	夜宿倫敦
90.06.14	四	英國	倫敦	參訪位於英國 SURREY 之 PRIMARY IMAGE GRAPHICS 公司，瞭解 PC 級影像產生器之系統整合與驗證，並蒐集相關技術資料。	夜宿倫敦
90.06.15	五	英國	倫敦	參訪位於英國	夜宿倫敦

日　期	星期	公差地點		工作項目	備考
				BURGESS HILL 之 SEOS 公司參訪平行光顯像系統之設計與驗證，並蒐集相關技術資料。	
90.06.16	六	英國	倫敦	返國行程	
90.06.17	日			於 21:45 返抵中正機場	

伍、　社交活動

無

陸、 建議事項

（1）對於外包合約的管理，是專案成功與否的重要因素之一。未來除了在購案的規格定義要明確外，應該建立與供應商的溝通管道，並透過工程討論、設計審查、派駐監造等方式，使得需求項目及設計方式能夠滿足採購之需求，以免等貨品交運驗收時，才發現無法滿足需求。

（2）視效資料庫對模擬器的發展一直是個問題，傳統大型影像產生器的視效資料庫都是封閉式的，無法互相交換使用，因此每次更換新的影像產生器系統，就必須重新建一次視效資料庫。PC 級影像產生器則已經出現一個共同的標準 OPENFLIGHT，這個標準日漸普及，也逐漸被一些傳統大型影像產生器採用，我們未來應該也朝這個方向來走。

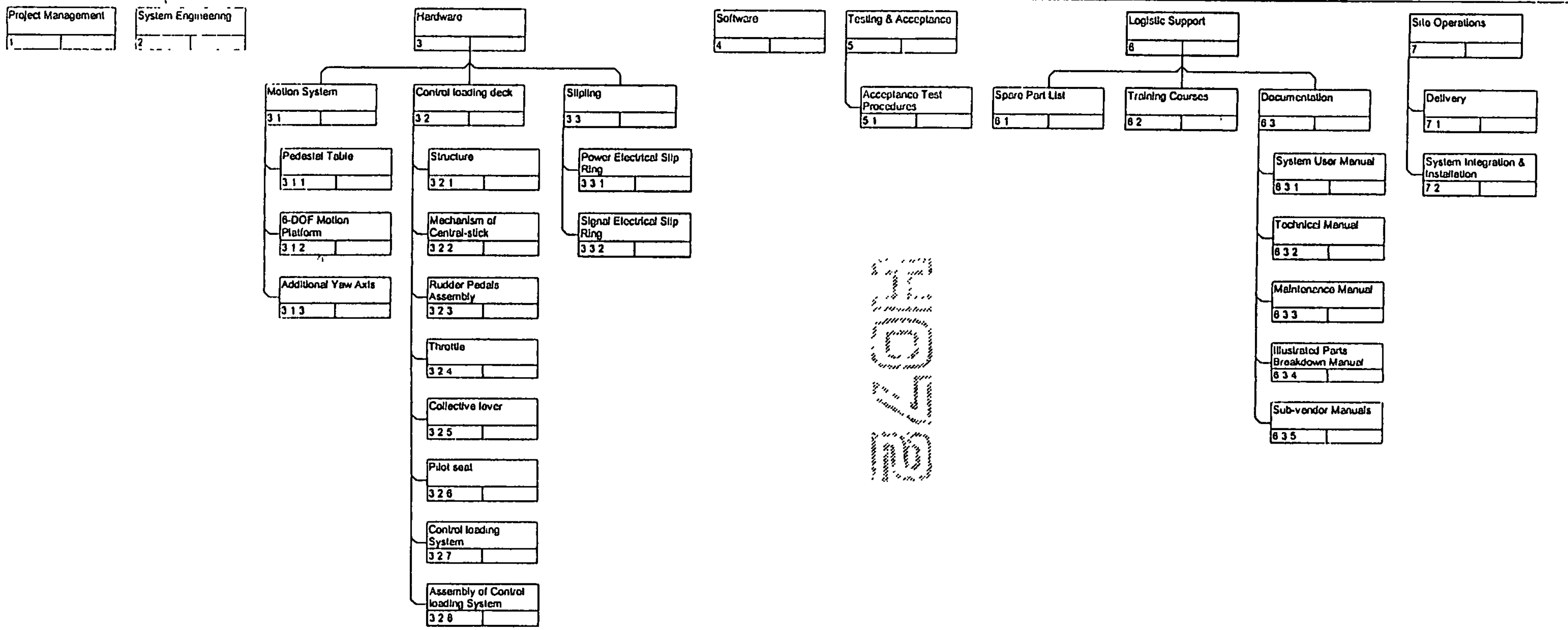
（3）從 PC 的處理器（CPU）及繪圖卡的快速發展，PC 級影像產生器將是未來的發展方向，甚至其取代大型主機式的視效系統日子應該不遠了，本組應加強 PC 級影像產生器相關領域的開發及應用研究。未來在新的模擬器中，尤其是非特殊視效需求的模擬器，可考慮採用此類之 PC 級視效主機。這對本組未來爭取低階訓練模擬器，在降低成本上應有較大的空間，相對應的也增加了價格的競爭力。

（4）荷蘭 DELFT 大學運用研究計劃，不僅結合該校資源，並與政府或企業研究機構有許多研究計劃在進行中，確切做到產官學合一的境界。這對政府積極推動科專計劃，如何結合產業需求至學習中及設備共用共享，是值得學習的對象。

AMST Systemtechnik Ges m b H

A 25032 ROC AF DISO
Work Breakdown Structure (WBS)

release date 08 0

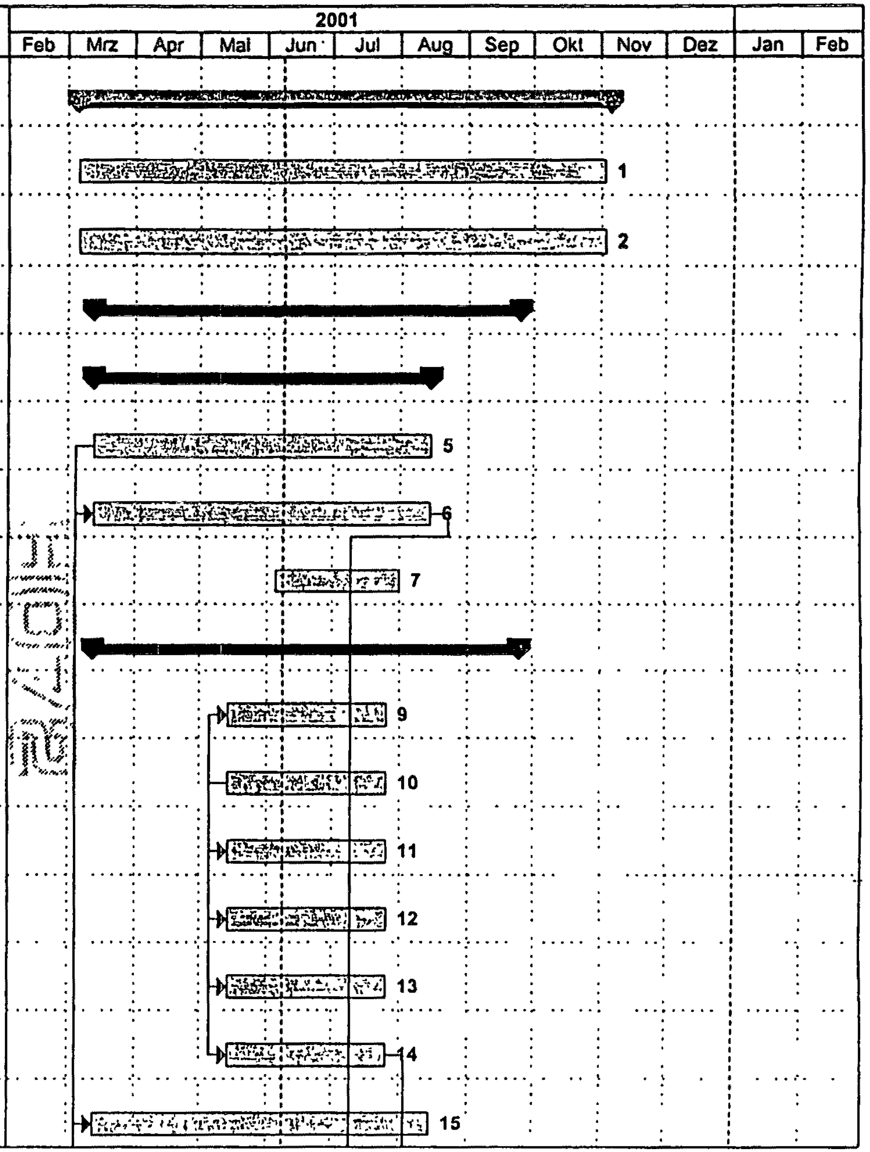


released

A 25032 Diso ROC Taw

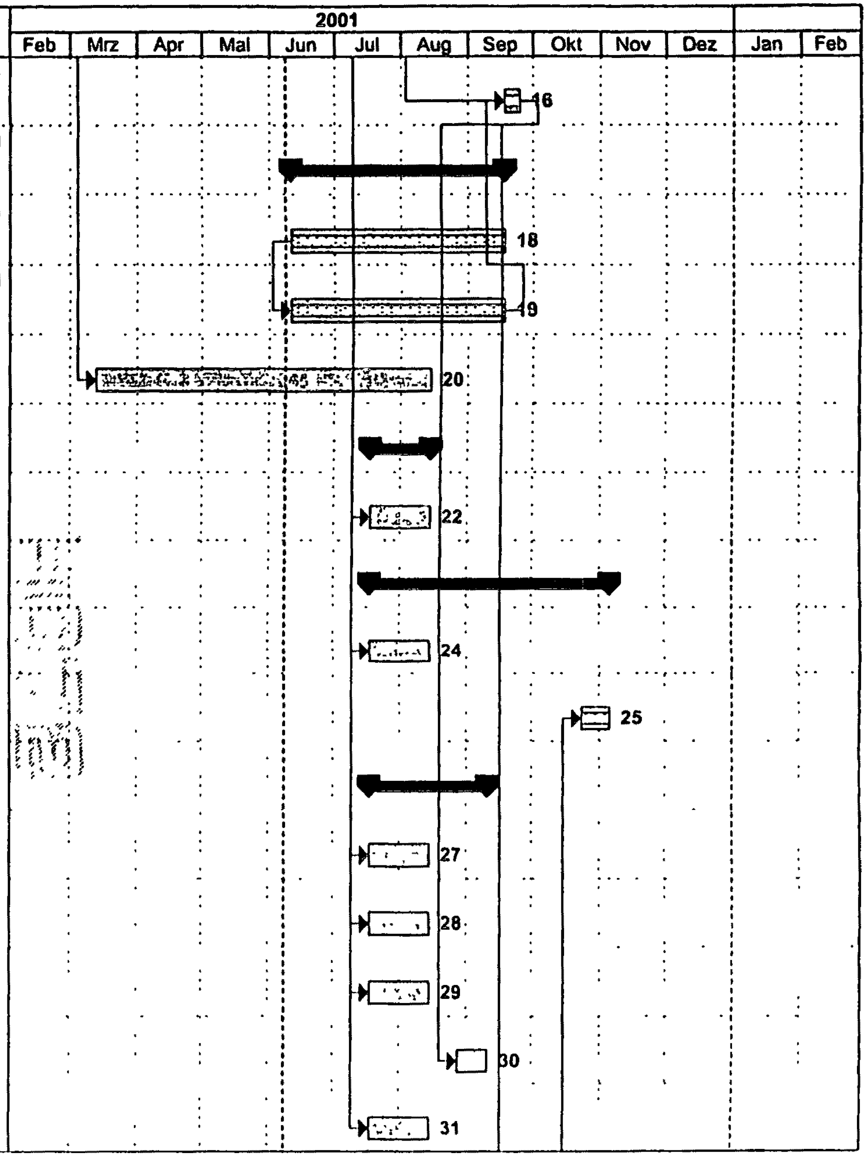
附件一

Nr.		PSP	Activity	Durat.	Start	End
0		0	**A.25032 Diso ROC Taiwan**	**33,4W**	**06.03.01**	**05.11.01**
1		1	Project Management	33,2W	06.03.01	02.11.01
2		2	System Engineering	33,2W	06.03.01	02.11.01
3		3	**Hardware**	**26,8W**	**13.03.01**	**24.09.01**
4		3.1	**Motion System**	**21W**	**13.03.01**	**14.08.01**
5		3.1 1	Pedestal Table	21W	13.03.01	14.08.01
6		3 1.2	6-DOF Motion Platform	21W	13.03.01	14.08.01
7		3 1 3	Additional Yaw Axis	8W	05.06.01	31.07.01
8		3.2	**Control loading deck**	**26,8W**	**13.03.01**	**24.09.01**
9		3.2 1	Structure	10W	14.05.01	25.07.01
10		3 2 2	Mechanism of Central-stick	10W	14.05.01	25.07.01
11		3 2 3	Rudder Pedals Assembly	10W	14.05.01	25.07.01
12		3 2 4	Throttle	10W	14.05.01	25.07.01
13		3 2.5	Collective lever	10W	14.05.01	25.07.01
14		3.2 6	Pilot seat	10W	14.05.01	25.07.01
15		3 2 7	Control loading System	21W	13.03.01	14.08.01

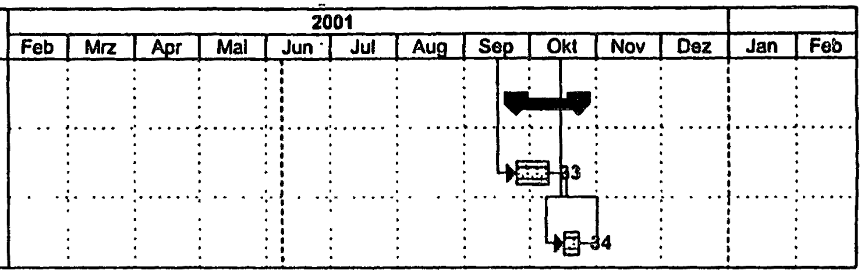


附件二

Nr		PSP	Activity	Durat.	Start	End
16		3 2 8	Assembly of Control loading System	1W	18.09.01	24.09.01
17		3 3	**Slipling**	**14W**	**11.06.01**	**17.09.01**
18		3 3 1	Power Electrical Slip Ring	14W	11.06 01	17.09.01
19		3 3 2	Signal Electrical Slip Ring	14W	11 06.01	17.09.01
20		4	Software	21W	13.03 01	14.08.01
21		5	**Testing & Acceptance**	**4W**	**18.07.01**	**14.08.01**
22		5 1	Acceptance Test Procedures	4W	18.07.01	14 08.01
23		6	**Logistic Support**	**15,4W**	**18.07.01**	**05.11.01**
24		6 1	Spare Part List	4W	18.07.01	14.08 01
25		6 2	Training Courses	1,6W	24.10 01	05.11.01
26		6 3	**Documentation**	**7,8W**	**18.07.01**	**10.09.01**
27		6 3 1	System User Manual	4W	18.07.01	14.08.01
28		6 3 2	Technical Manual	4W	18 07 01	14 08 01
29		6 3 3	Maintenance Manual	4W	18 07 01	14.08 01
30		6 3 4	Illustrated Parts Breakdown Manual	2W	28.08 01	10 09 01
31		6 3 5	Sub-vendor Manuals	4W	18 07 01	14 08 01



Nr.		FSP	Activity	Durat.	Start	End
32		7	Site Operations	4W	25.09.01	23.10.01
33		7 1	Delivery	2W	25.09.01	09.10.01
34		7 2	System Integration & Installation	1W	17.10.01	23.10.01



附件三

FAX MESSAGE

AMST · SYSTEMTECHNIK GES.M.B.H

TO

COMPANY:	HOTEL
CITY:	LONDON
ATTN..	MR. NIKKO NI Room No.: 36
PHONE:	
FAX:	0044-02-07821-5814

FROM:

NAME:	Richard Schluesselberger
ADDRESS:	Postfach 3
CITY:	A-5282 Ranshofen
PHONE:	++43/7722/892/
FAX:	++43/7722/892/99

CREATED	14-06-2001
PAGE 1 OF	3
ATTACHMENTS	1
SUBJECT	Slip Rings

L: 825 → 600 mm

Dear Nikko Ni,

we have been yesterday at the company which we would recommend for the design and manufacturing of the sliprings.

The following items we discussed and we should find until Whendsday next week a solution for all items which are listed below. 加外径 > 1000mm

1. the slipring has a length of 825 mm, this would be to long because we would have collision with the pneumatic cylinder. This arises because of the specification with the free inner diameter of 100 mm. Therefore, the diameter of the rings is 160 mm which causes the following design restrictions. The diameter is related to the height of the rings, and the insulation between the rings must be grater than the height of the ring. If the ring would be smaller, the size of the slipring would also be smaller. You specified 8 rings for power, each 240 V, 30 A. If we reduce this number to 2, the size of the slipring will be reduced down to about 600 mm, without loosing any performance.
2. The size of the ring (diameter) is strictly related to the frequency band which you want to transfer over the sliprings. If the size is 160 mm, the resonance frequency is about 55 Mhz, if the size goes down to about 80 mm diameter, this frequency is about 100 Mhz. In this case, the remaining inner diameter for air would be only 20 mm. You can transmit signals up to 100 Mhz, but there will be disturbances above 55 Mhz in case of the diameter will remain at 160 mm.
3. Sliprings should be solid gold alloy - this is only valid for miniature sliprings. The material of the slipring is copper and gold plated.

RJ45 4條

4對8

AMST - SYSTEMTECHNIK GES.M.B.H P O BOX 3 A-5282 RANSHOFEN FAX-SCHLEIFRING NIKKO DOC

TelePhone: ++43 7722 892-0 Telefax: ++43 7722 892-99 e-mail: office@amst.co.at Telex: 27301 amst

Bank Account: Bank für OÖ und Salzburg, Linz, BLZ 15040, Kto 201-2112/13 HG Ried im Innkreis, FN 115541 k DVR 052-397

AMST
AMST - SYSTEMTECHNIK GES.M.B.H

FAX MESSAGE

4. 4 contact points per ring – this would strictly influence the quality of signal transmission. They design for the signals 3 pairs of fethers as contact point to reduce the noice of the slipring during rotation. For the power slipring the use special brushes with carbon-graphite.
5. The definition for the noice with 5 uV peak to peak is wrong, it should be specified in milli Ohm (exact value we get until Monday).
6. For each ring system, this values have been copied, therefore they are in each specification of slipring partition.

The requirements with 100 and 150 MHz are in the mind of their specialists much to high and are not needed. Additionally, if such requirements are specified, you have to specify also for which purpose the single signal will be used. The requirements are normally 10 MHz, even for video signals.

What means s-video? We could not find this anywhere. Is it e special format?

What is the solution?

1. Either we go down with the diameter of the sliprings, than we can incrase the MHz to 100 and decrease the size of the slipring dramatically For the air transmission, we could find an other solution either with a similar design as we did it for our diso, or using pressurised air and a diameter for the air tube of about 20 mm, or you use an independent air supply by installing a low noice ventilation system inside the cabin.
2. We change the specification for some of the modules down to 10 MHz (not the Ethernet), and we use only 2 power sliprings. Than the size will be about 600 mm.

Please discuss this with your specialists.

I am in the office for the next one hour, or tomorrow. My mobile no. is 0043-664-5319414 or you can reach me in the office.

Kind regards

Richard Schluesselberger

0930 - 877838

AMST - SYSTEMTECHNIK GES.M.B.H · P.O. BOX 3 · A-5282 RANSHOFEN · FAX-SCHLEIFRING NIKKO DOC
Telephone ++43 7722 892-0 · Telefax ++43 7722 892-99 · e-mail: office@amst.co.at · Telex 27031 amst
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FAX MESSAGE

AMST · SYSTEMTECHNIK GES.M.B.H.

TO	COMPANY:	HOTEL
	CITY:	LONDON
	ATTN :	MR. NIKKO NI Room No.: 36
	PHONE:	
	FAX:	0044-2-07834-6018
FROM:	NAME.	Richard Schluesselberger
	ADDRESS.	Postfach 3
	CITY:	A-5282 Ranshofen
	PHONE·	++43/7722/892/
	FAX:	++43/7722/892/99
	CREATED	15-06-2001
	PAGE 1 OF	1
	ATTACHMENTS	1
	SUBJECT	Slip Rings

Dear Nikko Ni, H072

Thank you very much for your quick response, probably it costs you some hours of your night.

I have already discussed your answer with Manfred Knolz and he agrees with myself, that we accept your proposal.

So I can confirm you, that we will do the design changes for the seat and also the ventilation for cost free, as you mentioned in your fax.

We had already ordered the slipring on Whendsday and we are able to change the specification until Whendsday next week.

I leave the company tomorrow and will be back on Whendsday afternoon, but I will stay in contact with Manfred and SAF.

Kind regards

R. Schluesselberger

Richard Schluesselberger

AMST - SYSTEMTECHNIK GES M B H P O BOX 3 A-5282 RANSHOFEN BESTÄTIGUNG ÄNDERUNG NIKO.DOC
TelePhone ++43 7722 892-0 Telefax ++43 7722 892-99 e-mail office@amst.co.at Telex 27301 amst
Bank Account Bank für OÖ und Salzburg, Linz, BLZ 15040 Kto 201-0113/15 HG Ried im Innkreis, FN 115841 k DVR 0534897

附件四

FAX NO. : ++43 7722 8922 99

TO : Richard Schluesselberger

FROM: NIKO NI

Dear Richard,

After I discussed with my system engineer, Peter Yang. I will change the specification if you can agree the following items :

H072

① The Change Request for ~~chair~~ seat angle and movement (automatic control displacement) is free charge.

② AMST will ~~provide~~ design and provide the low noise ventilation in the bottom of control Loading Deck.

The spcification will be changed, ~~to stff~~ if we make a deal: ~~[illegible]~~

1. Audio Signal : reduce 2 sets (4 rings)
2. S-Video Signal : Don't need (5 rings)
3. Analog / Digital Signal : reduce 6 sets (12 rings)

4. Power : reduce 4 sets (8 rings)
(30A @ 220V)

5. The Diameter, I agree with your suggestion to reduce it

6. for Video signal : 150 MHz → 15 MHz

7. for Analog / Digital signal : 100 MHz → 10 MHz

If you agree it I will propose the formal request to ~~you~~. Solo aerospace.

#072

Niko Ni

15/06/01
11:13

AMST

Minutes of Meeting

P/A Nr.:	A.25032	**Name:**	DISO,ROC
Reg.:	Projektbesprechung am 08.06.01 – 12.06.01		
Comp.	AMST-Systemtechnik Ges.m.b.H.	**Ort:**	Besprechungszimmer EG
Von:	Manfred Knolz		
created	11.06.2001		

Teilnehmer: Schlüsselberger, Tischer, Knolz, Seemayer, CSIST, Soloaero

附件五

Topics: PDR-Meeting

Date: 08.06.2001

1. Spare part list should be delivered (especially from Fokker).
2. Software for the 7th axis should be included inwith the Fokker-Software.
3. The decision for the slipring should be made as soon as possible (within two weeks).
4. The figure of the natural frequency should be given by Fokker.
5. The vibration envelope model of the bearing of the 7th axis seems very important with respect of Diso-effects.
6. There is no operation mode of the Diso, where the 7th axis is in movement together with the 6 DOF platform.
7. The decision of the bearing should be made as soon as possible (within two weeks).
8. AMST gets drawings of the central stick as soon as possible (The grip including the electrical connections is provided by CSIST.
9. The figure of the payload has to be confirmed by Fokker (3500 kg).
10. The figure of the vertical acceleration has to be confirmed by Fokker (0,8 g).
11. The COG for the payload should be as big as possible (has to be discussed with Fokker). It should be more then 1 m.
12. The supply voltage in Taiwan is 208 V. According the technical description the Fokker system can be operated at any voltage. This has to be confirmed.
13. The upper pneumatic ring of the motion cue should be enlarged. This has to be discussed with Fokker.
14. The control loading deck which carries the seat etc. will be produced by AMST.
15. The changing of the specification of the seat (automatical displacement, seat angle change) will have the following impact from the current point of view:
    delivery-time: + 3 weeks
    cost: + 17.700 USD

Date: 11.06.01

16. CSIST will provide data of the cockpit (weight, connecting points, COG, equipment coordinates) for selecting the bearing and constructing the base frame, asap.
17. Brake shall be included inwith the 7th axis.
18. Software for the 7th axis shall be included in the Fokker PC-Hardware.
19. The upper triangle of Fokker shall not be used.
20. AMST will provide the base-frame for the cockpit.
21. AMST will provide drawings for the gondola structure fixation points, asap.
22. The inner diameter for the slipring can be 100 mm.
23. AMST and the two specialists from CSIST will visit the company SAF which delivers the splipring. During this meeting the specification of the slipring will be checked.
24. Training:
    The training for the CLS will be two days. The training for the Motion-Cue will be two days in Amsterdam and additional training will be in Ranshofen after installation. Fokker will try to get a training date for CLS in week 28/29. The training for the motion cue should be held at the same date, where the week before shipment of the motion cue to AMST is the ultimate possibility for training on the motion cue at Fokker site. The content of the training shall be according to the contract. The training shall be repeated in Taiwan.
25. CSIST residental engineers will join the inspection for the CLS and for the motion cue at Fokker site in Amsterdam before shipment to AMST.
26. Delivery time:
    CSIST agrees to prolong the delivery date to the 5th of November. AMST will inform Soloaero about the exact delivery time.
27. The acceptence test procedure will be within 40 days (instead of originally 45 days).
28. AMST will provide an updated time-schedule and WBS within one week

For the seller

Mr. Schlüsselberger Mr. Kholz Mr. Lou

For the buyer

Mr. Dr. Gao, Mr. Niko Ni

附件六

FCS Control Systems

Title:	Report no: MAMS_DSO_FRD
Facility Requirements Document **E-Cue 636-3500 Motion System**	Issue Date: April 2001 Security Class: Unclassified
Customer: AMST Simulator Type: 636-3500 Project Number: MAMS.DSO	Created by: R. van der Holst

Purpose/abstract of document:

This document describes the Facility Requirements of the E-Cue 636-3500 Motion System for AMST.

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DISTRIBUTION SHEET

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Date of distribution: April 2001		

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Prepared:	R. van der Holst	
Checked:	S. Streefkerk	
Approved FCS:	S. Streefkerk	

DOCUMENT CHANGE OVERVIEW

Date	Version	Description of changes	Pages
April 2001	1.0	First issue	All

TABLE OF CONTENTS

1. INTRODUCTION

This document describes the facility requirements of the E-Cue 636-3500 electric motion system for the AMST simulator. On top of the needed facility services (electrical, mechanical, environmental, etc.), an overview of the interfaces with the facility is given. Detailed information on these interfaces is given in the Interface Control Document.

2. MAIN SYSTEM DIMENSIONS

This Section handles the main simulator and surrounding equipment dimensions.

2.1 General Overview

Figure 2-1 gives a 3D impression of the simulator.

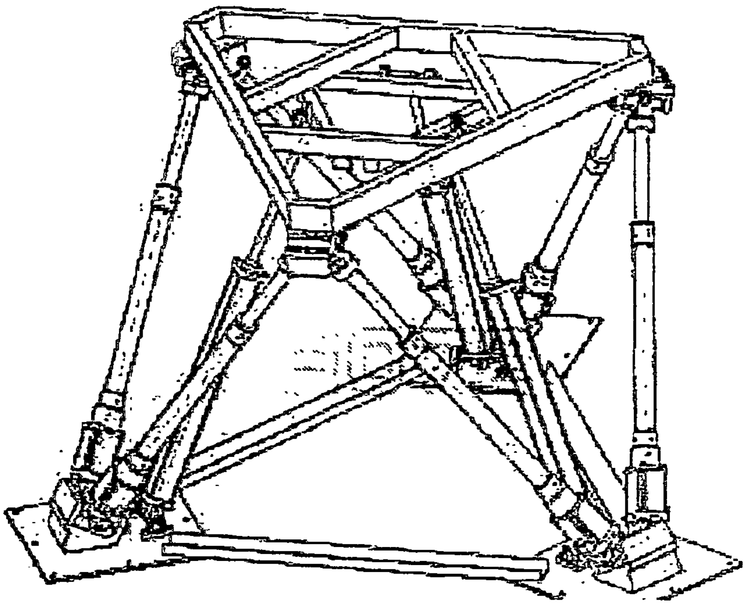

Figure 2-1 3D indicative view of the simulator

2.2 Room Clearance (Motion Envelope)

Figure 2-2 to 2-4 show the projection of the motion envelope of the E-cue 636-3500 with a standard block-shaped payload (4 x 4 x 4 meters) in three projections.

The extremes of the motion envelope are specified in table 2-1. The frame of reference used for these calculations is the following:

- Origin on the ground, directly below the Fixed Platform Centroid (FPC)
- X-axis, positive pointing forward
- Y-axis, positive pointing to the right
- Z-axis, positive pointing upwards

Table 2-1 Motion envelope extremes of the AMST E-Cue 636-3500 simulator

Direction	Minimum Excursion (m)	Maximum Excursion (m)	Total Motion Envelope (m)
• Longitudinal Direction	• -4.43	• +4.53	• 8.96
• Lateral Direction	• -4.4	• +4.47	• 8.87
• Vertical Direction	• 0	• +7.27	• 7.27

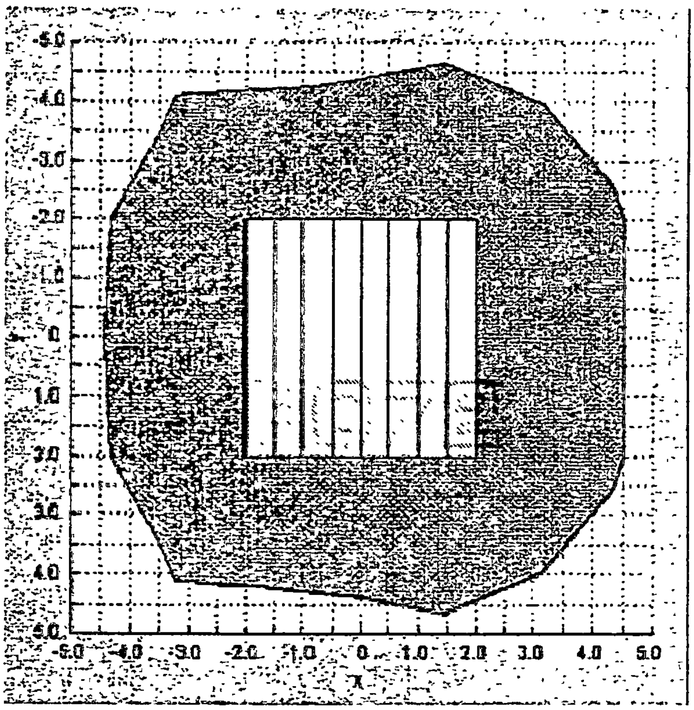

Figure 2-2 Top view of the motion envelope

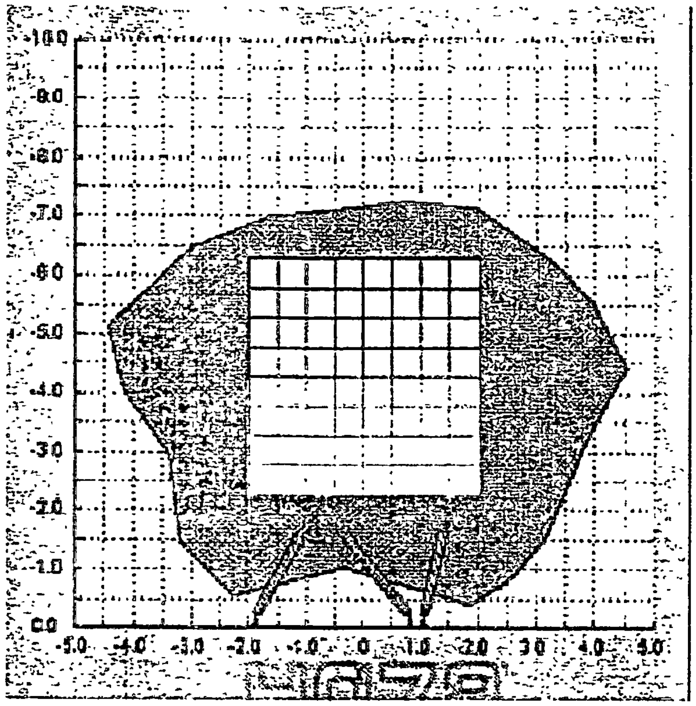

Figure 2-3 Side view of the motion envelope

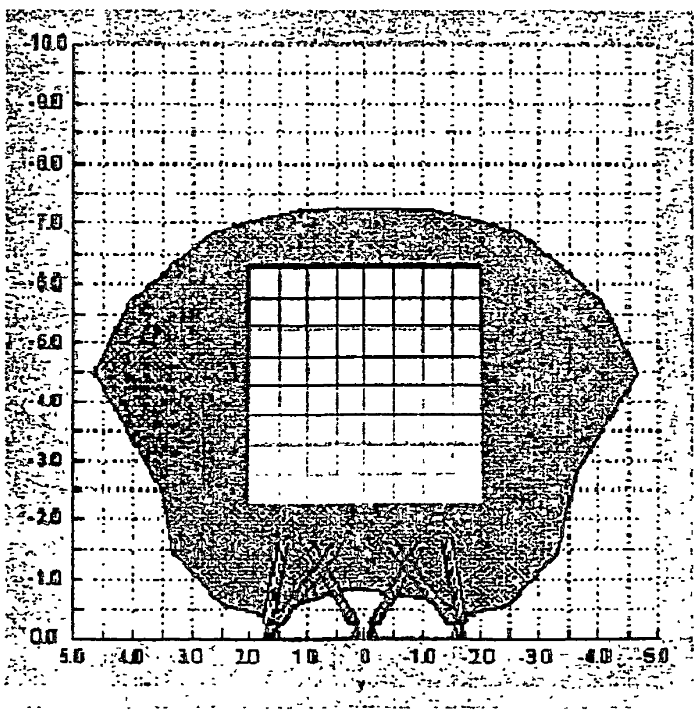

Figure 2-4 Aft view of the motion envelope

2.3 The Motion Control Cabinet

There is one Motion Control Cabinet for each motion base. The main dimensions of the control cabinet are: 2.0 x 2.00 x 0.80 m (Height x Width x Depth) (TBC). Mass is TBD.

2.3.1 UPS (Optional)

The UPS can be delivered as an option.

2.4 The Pneumatic Subsystem

The overall dimensions of the pneumatic subsystem of the E-cue 636-3500 are:

- Compressor: 860 x 760 x 430 mm (Height x Width x Depth)
- Pneumatic Reservoir: 1640 x 500 mm (Height x Diameter; when in upright orientation)

There is 1 compressor and 1 pneumatic reservoir for each motion base.

3. FLOOR LAYOUT PLAN

A floor layout plan, including the simulator and its Motion Envelope, the Motion Control Cabinet, cable routing, air conduction hoses, etc. should be agreed upon mutually. Basis for this floor layout is the Motion Envelope, which determines the minimum room clearance and, in fact, the position of the simulator. Surrounding equipment and connections should be positioned both practically and safely.

3.1.1 Ingress/Egress Ramp (Optional)

The Ramp is the interface between the building and the Simulator entrance.

3.1.2 Position of Floor Pads

A drawing of the floor pads is given in the ICD, drawing 99 537 002. The reference point for positioning of the floor pads relative to the facility is the Fixed Platform Centroid or FPC. The FPC represents the geometrical centre of the triangle through the floor pads.

3.1.3 Simulator Cable Routing (Proposal)

The Simulator cables are routed on the ground to the pneumatic cylinders. From there the cables are routed along the cylinders to the Motion Platform.

3.1.4 Cable and Pneumatic Hoses Routing

The Motion System cables are routed separately from the Motion Control Cabinet to the nearest floor pad. From there, the cables are routed through cable trays to the other two floor pads (and to the actuators).

The hoses for the pneumatic system are routed from the tank to the pneumatic support springs, if possible through the cable trays.

3.1.5 Air Conditioning Hoses

The proposed routing of the air conditioning hoses is TBD.

4. NEEDED SERVICES

This section describes the minimum necessary services needed for proper installation, operation and maintenance of the Motion System.

4.1 Mechanical Services

4.1.1 Installation Access

The Motion System will be shipped in parts, as there are: actuators, electronic cabinet, pneumatic system and mechanical constructions (simulator platform, joints, floor pads, etc.). The minimum door dimensions are therefore based on the dimensions of the largest part, which will be the simulator platform. FCS advises a door of at least 5 metres wide by 3 meters high. Entry to the building should be free of obstructions and on reasonably level ground.

4.1.2 Motion System Foundation

The motion system will be installed by bolting metal floor pads on the concrete. The loads are transferred to the floor by the metal bolts, which are chemically connected to the concrete floor. The proposed bolts (type Hilti, M24) will be installed using eight bolts per floor pad, which ensures enough strength capacity. Concrete should be B25 type (or better), reinforced concrete.

The concrete foundation can be triangular or rectangular shaped, whichever is convenient. It should be sized such that the minimum dimensions form the floor pads to the foundation-edge is **0.5 meters**. FCS advises a minimum concrete thickness of **260 mm**. The concrete should preferably be supported separate from the building foundation.

4.1.3 Transport & Handling Equipment

For installation of the motion system at Buyer's site, the following handling and transportation-equipment is necessary:

- Crane, 4 m height, 1500 kg minimum, including belts (2 cranes are preferred; 3 belts for upper frame, 1 for actuators, a safety belt)
- Forklift truck, 1500 kg
- Pallet forklift tool

4.2 Electrical Services

4.2.1 Electrical Power for Operation

The Motion System works with 400 VAC, 3 phase + neutral, 50/60 Hz, 32 A power circuit breaker, type C characteristics. The total power consumption is approximately 6 kVA, peak 18 kVA (one Motion system).

For the pneumatic system, the power requirements are:

Power consumption of the standard compressor is 1500 VA (intermittent)

- Power supply: 380-400 VAC, 3 phase + neutral, 50/60 Hz, 16 A
- Connector: IEC 400 V, 3 phase + N + PE, 16 A

4.2.2 Power During Installation

For installation and test, normal power outlets are used for electric hand-tools. Testing requires Electrical Power for Operation (4.2.1)

4.3 Environmental Conditions

4.3.1 Temperature

The Motion System is designed to operate within the temperature range of 24 ± 5° Celsius. Non-operating temperature may vary between –18° and + 41° Celsius.

4.3.2 Humidity

The Motion System is designed to operate within a relative humidity of 15% to 85% non-condensing. Non-operating humidity shall be within 10% to 80% non-condensing.

5. INTERFACES WITH THE FACILITY

All interfaces, among which are the interfaces with the facility, are described in the Interface Control Document (ICD). This Section gives a summary of the interfaces with the facility.

5.1 Mechanical Interfaces

Mechanical interfaces comprise:

- Interface with the ground (floor pads)
- Ingress/Egress ramp interface (optional)
- Cabling ducts interfaces of the Motion Control Cabinet
- Motion Control Cabinet interface (no requirements, only adequate floor space)
- Interface with 'waterfall' – hoses to simulator cabin (TBD)
- Air conditioning hoses (TBD)

5.2 Electrical Interfaces

Electrical interfaces comprise:

- Interface with the mains power
- Standard power outlets (for installation)
- Power for Pneumatic System

Control systems

Title: **Interface Control Document** **E-Cue 636-3500 Motion System for AMST**	Report no: MAMS_DSO_ICD Issue Date: February 2001 Security Class: Restricted
Customer: AMST Simulator Type: 636-3500 Project Number: MAMS.DSO	Created by: R. van der Holst

H072

Purpose/abstract of document:

This document specifies the Mechanical, Electrical and Software Interfaces of the E-Cue 636-3500 Motion System for AMST.

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Recipients	**Location**	**Quantity**
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Project File	Project office	1
Date of distribution: April 2001		

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Prepared:	R. van der Holst	
Checked:	S. Streefkerk	
Approved FCS:	S. Streefkerk	

DOCUMENT CHANGE OVERVIEW

Date	**Version**	**Description of changes**	**Pages**
April 2001	1.0	First issue	All

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

CoG	Center of Gravity
FPC	Fixed Platform Centroid
MPC	Moving Platform Centroid

1. INTRODUCTION

This document specifies the mechanical, electrical and software interfaces of the E-Cue 636-3500 Motion System for AMST.

3. MASS

This section describes the mass breakdown.

For the AMST E-Cue 636-3500 system, a maximum payload of 3500 kg was estimated. The approximate mass of the main components is specified in table 3-1.

Table 3-1 Approximate mass of AMST E-Cue 636-3500 system

Component	Mass (kg)	Moving Mass (kg)
Cabin	TBD	TBD
Frame	600	600
Actuators + Base Plates + Pneumatic Cylinders	2300	
Total Simulator Mass (kg)	TBD	
Total Simulator Moving Mass (kg)		TBD

3. MECHANICAL INTERFACES

3.1 Interface with the Facility

3.1.1 Floor Pads

The motion system is mounted to the facility floor by means of three floor pads that can be individually positioned and bolted to the facility floor. On one floor pad, one actuator joint assembly is bolted and one joint assembly for the pneumatic support spring.

- An overview of the floor pads, wedges and the actuators is shown by drawing 99 537 001.
- The positioning of the three floor pads relative to each other is specified by drawing 99 537 002. A detailed drawing of the plate is 99 537 007.
- The dimensioning of the floor pads are based on the use of M24 Hilti chemical plugs in a concrete floor. The holes in the plates will be 30 mm in order to use as a template for drilling the holes in the concrete floor. The diameter of the drill is 28.6 mm.
- The holes in the cable ducts and floor pads are drilled accurately. This makes it possible to use the cable ducts for the positioning of the pads.

3.1.2 Worst-case Floor Loading

There are three floor pads with a size of 1000 mm X 1000 mm. Each floor pad carries the forces generated by one pair of actuators.

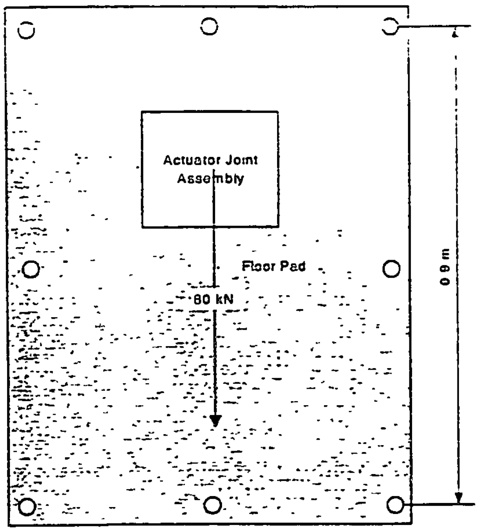
Each pad is mounted to the concrete floor or block by means of eight M24 Hilti bolts. The minimum thickness of the concrete floor, as specified by Hilti, is 260 mm. The required mass of the floor / block will generally lead to an even thicker floor.

A typical worst-case load is a double actuator (both actuators mounted to one floor pad) runaway, resulting in tension forces in the actuators of 80 kN.

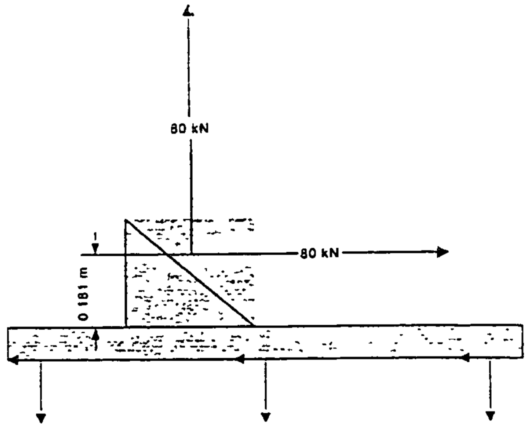
The actuator forces can be resolved into a vertical force of 80 kN and a simultaneous horizontal force of 80 kN, acting in the joint center (see figure 3-1).

The horizontal load of 80 kN causes a shear load between the steel plate and the concrete floor. The total preload of the bolts is 8 X 50 kN = 400 kN. Assuming a friction coefficient of 0.2 between steel plate and concrete block, a maximum shear load can be transmitted by friction of 400 X 0.2 = 80 kN. The remaining 80 – 80 = 0 kN is distributed over 8 bolts resulting in a shear load per bolt of 0 kN. Assuming a friction coefficient of 0.1 between steel plate and concrete block, a maximum shear load can be transmitted by friction of 400 X 0.1 = 40 kN. The remaining 80 – 40 = 40 kN is distributed over 8 bolts resulting in a shear load per bolt of 5 kN.

The vertical load of 80 kN causes an approximately equal tensile force in five of the eight bolts, resulting in a tensile force of 80 / 5 = 16 kN per bolt.



Top view of floor pad



Side view of floor pad

Figure 3-1 Mechanical loads on floor pads

The maximum allowed load on one M24 Hilti bolt (excluding safety factor 2.5) is 37 kN independent of direction and assuming a minimum concrete quality B25.

If the distance between the bolts is 450 mm instead of 520 mm (the distance at which full load is possible) the maximum load is 37 X ((1+(450/520))/2) = 34 kN.

The preload on each Hilti bolt is 50 kN, corresponding to a 200 Nm tightening torque.

The bolts with the highest loads combine a tension of 16 kN with a shear force of 5 kN (assuming a friction coefficient of 0.1) and are loaded within the limit of 34 kN total force.

Because the chemical plugs are designed with a safety factor 2.5 it is advised to apply the same or a higher safety factor for the surrounding concrete structure.

3.2 Simulator Ingress/ Egress Ramp (Optional)

TBD

3.3 Interface with the Cabin Frame

The motion system is delivered with a standard upper triangle, which is shown by drawing 99 537 003.

3.4 Pneumatic System

The pneumatic system comprises three pneumatic cylinders. Each cylinder is mounted between a floor pad and the upper triangle and is connected by a hose to a pressure vessel located close to the motion system. A compressor controls the pressure in the pressure vessel.

The standard low noise air compressor can be located close to the pressure vessel or in a separate room. Its dimensions are 830 mm (width) X 540 mm (depth) X 1060 mm (height). The pressure vessel has a 270-litre capacity and is positioned vertically. Dimensions (without appendages): diameter 500 mm, height 1640 mm.

3.5 Motion Envelope

Figure 3-2 to 3-4 show the projection of the motion envelope of the AMST E-Cue 636-3500 simulator in three projections. As the cabin dimensions are not known, a 4 m X 4 m X 4 m cube was used for the envelope calculations.

The extremes of the motion envelope are specified in table 3-1. The frame of reference used for these calculations is the following:

- Origin on the ground, directly below the Fixed Platform Centroid (FPC)
- X-axis, positive pointing forward
- Y-axis, positive pointing to the right
- Z-axis, positive pointing upwards

Table 3-1 Motion envelope extremes of the AMST E-Cue 636-3500 simulator

Direction	Minimum Excursion (m)	Maximum Excursion (m)	Total Motion Envelope (m)
Longitudinal Direction	-4.43	+4.53	8.96
Lateral Direction	-4.4	+4.47	8.87
Vertical Direction	0	+7.27	7.27

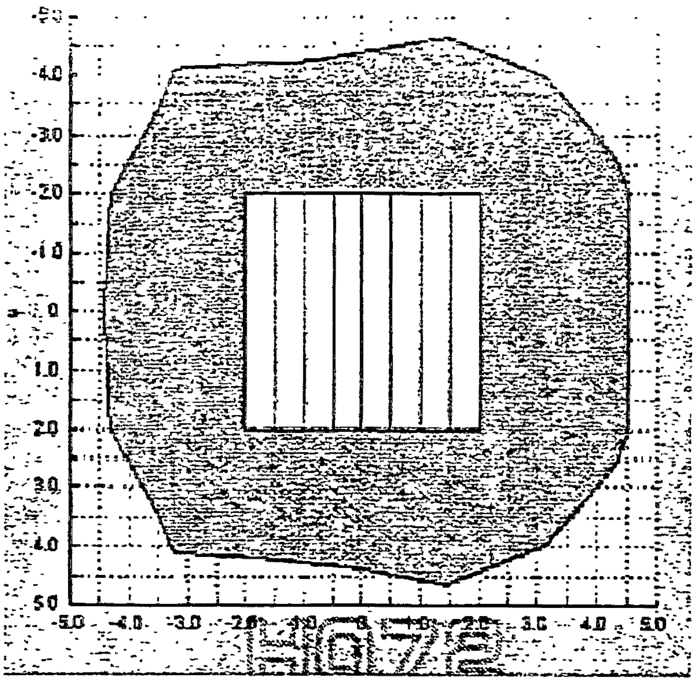


Figure 3-2 Top view of the motion envelope

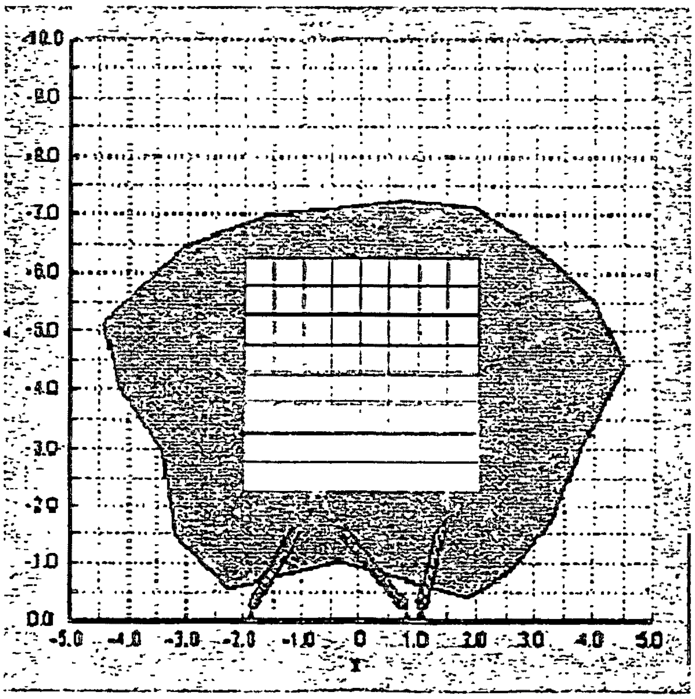


Figure 3-3 Side view of the motion envelope

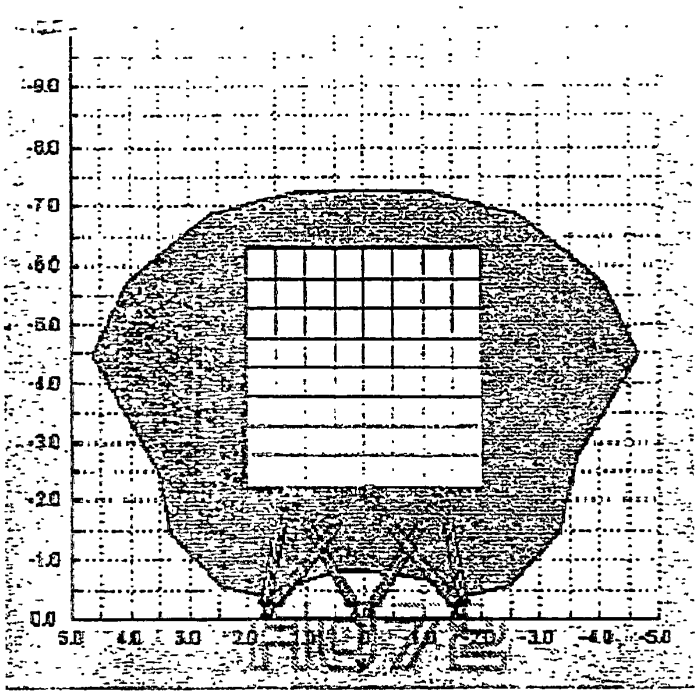


Figure 3-4 Aft view of the motion envelope

4. ELECTRICAL INTERFACE

4.1 Mains Power

380-400 VAC, 3 phase + neutral, 50/60 Hz, 32 A, circuit breakers 'C' characteristic.

Connector: IEC 400 V, 3 phase + N + PE, 32 A

4.2 Emergency Stop Interlock

The electric specification for the emergency interlocks is 24 VDC, max 34 mA. A description of the emergency stop interlock is given in the System Design Report (SDR).

4.3 User Interlock Circuit

The electric specification for the user interlocks is 24 VDC, max 34 mA. A description of the user interlock circuit is given in the SDR.

4.4 Pneumatic Compressor Power

The power consumption of the standard compressor is 1500 Watt (intermittent).

Power supply: 380-400 VAC, 3 phase + neutral, 50/60 Hz, 16 A

Connector: IEC 400 V, 3 phase + N + PE, 16 A

4.5 Simulator Ingress/ Egress Ramp (Optional)

The ingress/egress ramp electrical interface is in general a 24 Volts logic interface for ramp control and ramp position detection:

1. Ramp up command
2. Ramp down command
3. Ramp up switch
4. Ramp up switch (redundant)
5. Ramp down switch

Switches are considered normally open, unless activated (i.e. when the bridge is up, the up-switches are closed and the down-switch is open). Ramp up and down command is a 24 Volts signal.

5. MOTION SOFTWARE CONFIGURATION

The motion software has a large number of free parameters, which are loaded from the hard disk of the motion real-time computer during software initialisation. The parameters are contained in a number of so-called configuration files. Each of these files is a normal text-file, which can be edited by the use of a normal editor or (some) using the FCS Explorer. Table 5-1 lists the configuration files, and their location on the hard disk of the motion real-time computer.

Table 5-1 Configuration files of the motion software

#	Name	Description	Location
1	Bootline.dat	VxWorks configuration file listing boot information and Ethernet IP addresses and motion real-time computer name	C:\
2	Comm.dat	Configuration file listing UDP and TCP/IP port numbers, modem initialisation data etc.	C:\
3	Password.dat	Password configuration file listing users of the FCS Explorer and their security authorisation	C:\
4	PppOpt.dat	Modem configuration file	C:\
5	IoCard.dat	Configuration file listing the type and number of interface cards of the motion real-time computer	
6	MotAct.dat	Configuration file listing actuator data	C:\ecueconf
7	MotAcu.dat	Configuration file listing the defined tuning sets of the actuator controllers	
8	MotCtrl.dat	Configuration file specifying for each operational state of the motion cueing model and the actuator controllers, which model and tuning set is to be executed	C:\ecueconf
9	MotGuard.dat	Configuration file listing the defined tuning sets of the operational and safety guards of the motion controller and actuator controllers	C:\ecueconf
10	MotHw.dat	Configuration file listing the software bindings of external analog and discrete signals and internal software variables	C:\ecueconf
11	MotModel.dat	Configuration file listing the defined tuning sets of the motion cueing model (s)	C:\ecueconf
12	Motnode.dat	Configuration file specifying the nodes on which the motion controller and actuator controllers are running	C:\ecueconf
13	MotTrace.dat	Configuration file specifying time traces (not used)	C:\ecueconf

The configuration files 'bootline.dat' and 'comm.dat' are specified in the next sections.

5.1 The 'bootline.dat' Configuration File

During booting of the motion real-time computer, the VxWorks operating system reads the configuration file 'bootline.dat', which is stored in the root of the motion real-time computer's hard disk. This configuration file contains several boot configurations of which, however, only one should be active. The IP-address and logical name of the motion real-time computer are part of a boot configuration. The customer can edit this configuration file in a standard editor to specify the IP-address and logical name whenever required.

A boot configuration is the following group of lines:

```
#------------------------------------------------------------------------
# Boot configuration: 'Local harddisk'
#------------------------------------------------------------------------
MT := Boot local harddisk - Application local harddisk
BL := ata=0,0(0,0)host:/ata0/vxWorks e=194.0.0.85 h=194.0.0.130 u=vxworks pw=fcsworks
      f=0x0 tn=rtn-1
AL := md=LOCAL mp=appl mn=jetset.o en=InitMain cd=ata nd=fei
DL := NO
#------------------------------------------------------------------------
```

The labels MT, BL, AL and DL are explained below. Comment lines start with the #-character.

Menu Text (MT)

The Menu Text is for information only: the content does not affect normal operation. Here some boot specific data can be entered, which is presented during the first part of the boot sequence. Syntax:

```
MT := <Enter boot menu text here>
```

Boot Line (BL)

The boot line specifies the following:

- Boot device and location of VxWorks Board Support Package (BSP)
- IP-address of motion real-time computer
- IP-address of maintenance computer (only necessary when the motion application and configuration files have to be downloaded from the maintenance computer using FTP)
- The user name for download via FTP
- The password for FTP download
- Flag set to 0x0, do not change this one
- Target name, this is the computer name for the motion real-time computer

The BL has the following syntax:

```
BL := <device for BSP> <path and name of BSP> <IPaddress of CLC> <IPaddress of FTP host>
      <FTP user name> <FTP user password> <flags> <target name>
```

The device for the VxWorks BSP is set to one of the following options:

- Floppy disk, set <device for BSP> to: fd=0,0(0,0)
- Hard disk, set <device for BSP> to: ata=0,0(0,0)
- ELT network card, set <device for BSP> to: elt(0,0)
- FEI[a] network card, set <device for BSP> to: fei(0,0)

The path and name for the VxWorks BSP is set to one of the following options:

- When using a floppy disk, set <path and name> to: host:/fd0/vxWorks
- When using a hard disk, set <path and name> to: host:/ata0/vxWorks
- When using the network, set <path and name> to: pc30:/Tornado/target/config/fcs_bsp/vxWorks

The boot line defines the following IP-addresses:

- Motion real-time computer is set to: e=194.0.0.81
- Maintenance (or host) computer is set to: h=194.0.0.130

The IP-addresses depend on the local network subnet ID; here the example is based on subnet 194.0.0.

When using FTP on the network for downloading the BSP, an user name has to be set inside the (W)FTP program under the Security, Users/rights. This user name is the same as set in the boot line with: u=vxworks

[a] The FEI card = Intel EtherExpress Pro100B

When using FTP on the network for downloading the BSP, a password has to be set inside the (W)FTP program under the Security, Users/rights[b]. This password is the same as set in the boot line with: u=fcsworks

The flag field in the boot line is normally set to 0x0, only in case of user BOOTP server (non-regular configuration) it has to be set to 0x40.

The <target name> is the symbolic name of the real-time node and normally set to: tn=rtn-1. This target name is important for the configuration of the application.

Application Line (AL)

The AL is required for download of the proper real-time application and its configuration files. An additional option can be set for console output redirect. This line defines the following items:

- Boot device and location of ECue application
- Application name
- Application entry point (do not change this)
- Configuration device and location of application configuration files
- Local device for working directory (not used)
- Network device for external communication
- Virtual console for screen output redirect

The AL has the following syntax:

```
AL := <device for App> <path of App> <name of App> <App entry point> <device for App config files>
<location of App config files> <local device> <network device> <virtual console>
```

The device for the application is set to one of the following options:

- Floppy disk or hard disk, set <device for App> to: md=LOCAL
- Network card (ELT or FEI), set <device for App> to: md=NETWORK

The path for the application is set to one of the following options:

- When using a floppy disk or hard disk, set <path of App> to: mp=./
- When using the network, set <path of App> to: mp=d:/fcsrealtime/customer/ecue

The application name is equal to the object file, i.e. the executable that runs under vxWorks. It is set by: mn=generic2.o

The application entry point is always set to: en=InitMain. Do not change this setting.

The device for reading the application configuration files from is set to one of the following:

- Floppy disk, set <device for App config files> to: cd=fd
- Hard disk, set <device for App config files> to: cd=ata
- Network card (ELT or FEI), set <device for App config files> to: cd=NETWORK

[b] Ensure that the FTP program has a home directory that is properly set to the root of the vxworks BSP

The path for the App config files is set to one of the following options:

- When using a floppy disk or hard disk, the <path of App> is not set
- When using the network, set <path of App config files> to: cp=d:/fcsrealtime/customer/ecue/ecueconf

The network device for external configuration has to be set to:

- When using an ELT network card, the <network device> is set to: nd=elt
- When using a FEI network card, set <network device> to: nd=fei

Note that the device names have to match with the device name set in the Boot Line when NETWORK is selected for BSP download.

The Motion application has some initial output to a display and might print statements on the screen in case of an Error or a Warning. In normal cases the motion real-time computer will not have a display connected to the computer. However for debugging and maintenance, a feature is added which redirects output from the screen to the serial COM port. The virtual console can be set to: COM1, COM2, COM3, or COM4. For presentation on a maintenance PC, a serial line should be connected to the COM ports and the HyperTerminal application (when using a Windows PC) should be configured and running. The virtual console can be left out of the Application line.

Default Line (DL)

The 'bootline.dat' file can have more than one setting for the combination MT/BL/AL/DL. To activate one of the settings, the default line DL has to be set to:

```
DL := YES
```

otherwise set to:

```
DL := NO
```

Note that when more than one combination has a DL := YES, the first in the row will be applied.

5.2 The 'comm.dat' Configuration File

The configuration file 'comm.dat' lists configuration data of Ethernet UDP and TCP communication, RS-232, and modem. An example of the configuration file is shown below. The customer can edit this configuration file in a standard editor.

```
COMMUNICATION_CONFIGURATION_FILE
          BROADCAST_PORT 1700
          TCP_PORT       1701
          UDP_PORT       1702

          SPY_PORT       1705
          SPY_IP_ADDRESS 194.0.0.188
          SPY_ENABLED    false

          RS232          COM2    57600   8      N      1
          RS232_PPP      172.30.101.200 172.30.101.201

          DIALUP         COM1    57600   8      N      1
          DIALUP_MDM     ATZ     ATS0=2
          DIALUP_PPP     172.30.101.200 172.30.101.201
ENDDEF    COMMUNICATION_CONFIGURATION_FILE
```

An explanation of the labels is given in table 5-2.

Table 5-2 Specification of configuration items in the 'comm.dat' file

Keyword	Arguments	Explanation
BROADCAST_PORT	Integer	Port number of
TCP_PORT	Integer	Port number of TCP communication over Ethernet
UDP_PORT	Integer	Port number of UDP communication over Ethernet
SPY_PORT	Integer	Port number of second return port (Motion_To_Host DataPacket can be returned to a second address. Configuration in comm.dat.)
SPY_IP_ADDRESS	IP address TCP	IP address of second return port
SPY_ENABLED	Boolean	Feature enabled or disabled.
RS232	Field 1: COM# (#=com port number)	RS232 com port configuration data
	Field 2: baud rate	
	Field 3: number of data bits	
	Field 4: parity Y/N	
	Field 5: number of stop bits	
RS232_PPP	Field 1: IP address TCP	IP addresses for RS232 communication using PPP protocol
	Field 2. IP address UDP	
DIALUP	Field 1: COM# (#=com port number)	RS232 com port configuration data for external modem connected at com port
	Field 2: baud rate	
	Field 3: number of data bits	
	Field 4: parity Y/N	
	Field 5: number of stop bits	
DIALUP_MDM	Character string	Modem initialisation string
		Auto answer must be on
DIALUP_PPP	Field 1: IP address TCP	IP addresses for external modem communication using PPP protocol
	Field 2: IP address UDP	

6. SOFTWARE INTERFACES OF THE MOTION REAL-TIME COMPUTER

6.1 Introduction

Figure 6-1 shows the motion real-time computer and it's software interfaces with the host computer, the maintenance computer and several utility computers running the FCS Explorer software. Ethernet is used as the interface with the host and as the primary interface with a Windows 95/98/NT computer running the FCS Explorer software. Secondary interfaces available for the FCS Explorer are RS-232 and external modems that can interface with the motion real-time computer using RS-232.

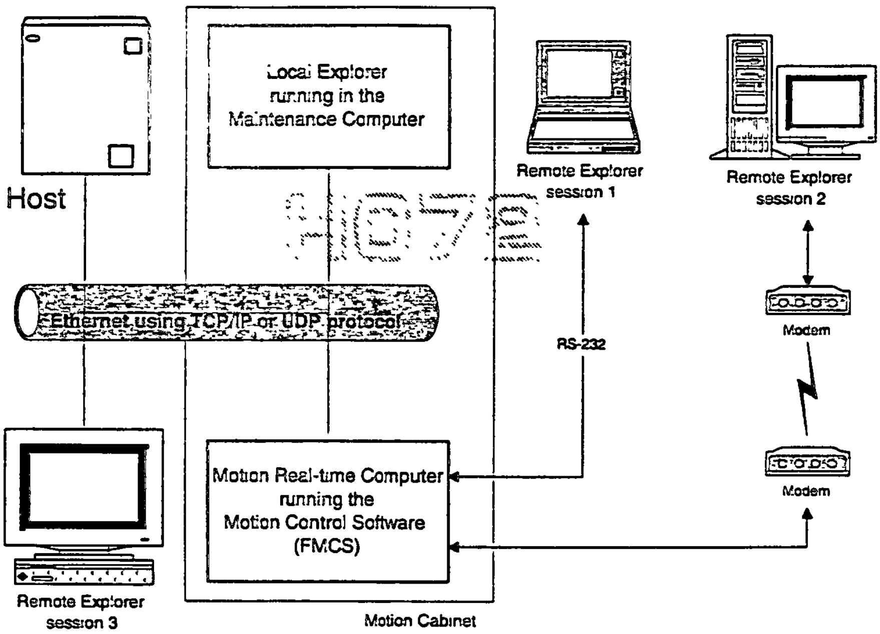


Figure 6-1 The motion real-time computer and its software interfaces

For the transport of data over Ethernet, the motion software supports both the TCP as the UDP protocol. For communication with the host UDP is recommended for performance reasons although TCP is possible. The communication between the FCS Explorer and the motion software uses TCP.

On top of the TCP and UDP protocol, FCS Control Systems has defined a simple protocol, the FCS protocol, as a means to build a flexible communication language between the host, motion real-time computer and FCS Explorer. For software engineers at the host side the FCS protocol does not add complexity. Depending on the choice for UDP or TCP communication with the motion real-time computer, the FCS protocol datagram (header + data) just fits in the UDP or TCP datagram data area.

The next section 6.2 in this chapter is essential for software engineers who write the Ethernet UDP interface on the host side. The Ethernet interface hardware is described along with the UDP, TCP and FCS software protocols. Furthermore the section specifies a few FCS protocol datagram definitions that are used for setting-up and terminating an UDP communication link, and are used for normal communication between the host and the motion real-time computer.

Section 6.3 specifies the data buffers used for normal communication between the motion system and the host. Section 6.4 specifies the state machine of the motion system as implemented in the motion software and the conditions for state transients. A correct understanding of this state machine for the software engineers on the host side is essential for the correct design and programming of the motion interface software within the host.

6.2 The Ethernet Interface

6.2.1 Ethernet Hardware

The Ethernet interface hardware consists of the following:

- An Ethernet card provided by the customer on the host side;
- An Intel Fast Ethernet card on the motion real-time computer side. Standard: 10 Mbit coax/UTP or 100 Mbit UTP.

6.2.2 The UDP Protocol

User Datagram Protocol (UDP) provides a simple datagram-based process-to-process communication mechanism. UDP provides protocol ports used to distinguish among multiple programs running on a single machine. That is, in addition to the data send, each UDP message contains both a destination port number and a source port number, making it possible for the UDP software on the destination to deliver the message to the correct recipient and for the recipient to send a reply.

UDP uses the underlying Internet Protocol to transport a message from one machine to another, and provides the same unreliable, connectionless datagram delivery semantics as IP. It does not use acknowledgements to make sure that messages arrive, it does not order incoming messages, and does not provide feedback to control the rate at which the information flows between the machines. Thus, UDP messages can be lost, duplicated, or arrive out of order. Furthermore, packets can arrive faster than the recipient can process them.

The motion software, however, is capable of handling these shortcomings of UDP. It is not a problem if one message is lost because the normal real-time communication between the host and motion real-time computer is repetitive. During the initialisation of a communication link between the host and motion real-time computer when this is not the case, the FCS protocol embedded in the UDP protocol provides for a simple acknowledge mechanism. An advantage of UDP is that it provides less overhead than the TCP/IP protocol. For this reason UDP recommended as the protocol between the host simulation and the motion real-time computer.

6.2.3 The TCP/IP Protocol

Unlike UDP, the Transmission Control Protocol (TCP) provides an acknowledgement mechanism for each packet send. Like UDP, the TCP/IP protocol uses ports to identify the ultimate destination of a TCP/IP message within the destination machine. TCP however regards the combination of IP-address and port number of both the source and the destination as two endpoints of a connection. The difference with UDP is that this way more than one process can use the same port number for TCP communication. Because TCP is a connection-oriented protocol, both endpoints need to agree to participate. Setting up a communication link, a connection is therefore more complex for TCP than for UDP.

The communication between the FCS Explorer and the motion real-time computer mainly relies on non-repetitive Ethernet messages. Therefore the FCS Explorer communicates with the motion real-time computer using the TCP protocol.

6.2.4 The FCS Datagram Protocol

Within the TCP and UDP protocol, FCS Control Systems has defined a simple embedded protocol, called the FCS datagram protocol (refer to figure 6.2). This protocol is used to define and implement a rich communication language in form of Remote Procedure Calls (RPC) between the motion real-time computer and its clients. This is especially needed for communication between the FCS Explorer and the motion real-time computer.

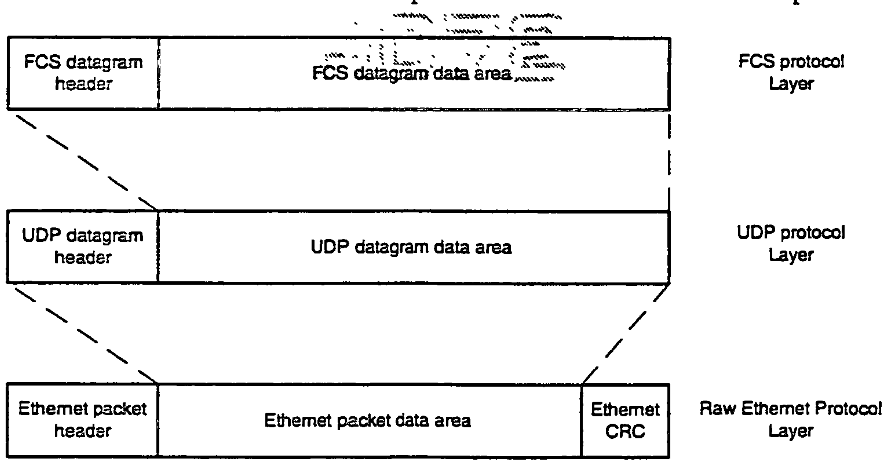


Figure 6-2 The FCS protocol embedded within the UPD protocol

The standard communication between the host and the motion real-time computer uses only the following five RPC's:

Table 6-1 The RPC's used for normal communication between host and motion real-time computer

#	RPC	Source	Destination	Purpose
1	CONFIGURE	Host	Motion real-time computer	Setting up a communication link
2	ACK	Motion real-time computer	Host	Acknowledgment (that the communication link is established)
3	HOST_TO_MOTION	Host	Motion real-time computer	Sending motion command word and vehicle dynamic data to the motion real-time computer
4	MOTION_TO_HOST	Motion real-time computer	Host	Sending motion status information to the host
5	DISCONNECT	Host	Motion real-time computer	Closing a communication link with the host

Table 6-2 specifies the FCS datagram header for the RPC's specified in table 6-1. As indicated in the table, the FCS datagram data area contents and size varies depending on the type of RPC.

Table 6-2 FCS protocol datagram headers

Field name	Type	Byte Number	Configure Header	ACK Header	Host to Motion Header	Motion to Host Header	Disconnect Header	Remark
Destination Process	Unsigned short	0-1	0	1	0	1	0	Addressing info of sender application software object
Destination Object	Unsigned short	2-3	0	0	0	0	0	
Source Process	Unsigned short	4-5	1	0	1	0	1	Addressing info of destination application software object
Source Object	Unsigned short	6-7	0	0	0	0	0	
Message Type	Unsigned short	8-9	9	3	0	1	7	Type of RPC type
Object Type	Unsigned short	10-11	1	2	1	4	1	Type of sender object
Wait for Acknowledge	Unsigned short	12	0	0	0	0	0	Ack required or not
Data Length	Char	13-16	0	0	Byte size of datagram	Byte size of datagram	0	Byte length of datagram data area
Additional Info	Char	17	0	0	0	0	0	
Version Number	Unsigned short	18-19	1	1	1	1	1	Header version number
Message Count	Unsigned short	20-23	Any	0	Any	Any	1	Frame counter
Datagram Data Area			Empty	Empty	Refer to Section 6.3	Refer to Section 6.3	Empty	FCS Protocol Datagram Data Area. Contents depends on RPC

6.2.5 Specification of IP-address, Port Number and Motion Real-time Computer Name

IP-address and motion real-time computer name can be specified by the customer in the configuration file 'bootline.dat', which is stored in the root directory of the motion real-time computer's hard disk. Refer to section 5.1 for details.

The communication ports to be used for TCP/IP and UDP ethernet communication can be specified by the customer in the configuration file 'comm.dat'. This file is also stored in the root directory of the motion real-time computer. Refer to section 5.2 for details.

6.2.6 UDP Communication Set-up

During booting of the motion real-time computer, the VxWorks operating system reads the configuration file 'bootline.dat', which is stored in the root of the motion real-time computer's hard disk. This configuration file contains one active boot configuration, which includes the IP-address of the motion real-time computer (refer to section 6.2.4 and section 5.1). During the initialisation of the motion software, the Ethernet port numbers for UDP and TCP are read from the configuration file 'comm.dat' (refer to section 6.2.4 and section 5.2). With this information, the motion software creates a UDP socket, which is bonded to the specified port numbers. The motion software then continues by reading the other motion application configuration files listed in table 5-1. When this is completed, the motion software is ready to accept UDP messages from the host.

After initialisation of the motion software as described above, the host application can request to open a communication channel with the motion real-time computer by sending one *CONFIGURE* datagram to the address and port of the motion real-time computer socket. When this message is received correctly, and no other host is already connected, the motion software will respond with one *ACK* (acknowledge) message indicating to the host that the connection is established. The communication link is ready for transfer of regular data packets as described in section 6.2.7 after both sockets are virtually connected, as indicated by the *ACK* reply. It is necessary to re-transmit the *CONFIGURE* message when the host has not received the *ACK* message within 1 sec.

The following scenario diagram shows the steps in establishing socket communications with UDP:

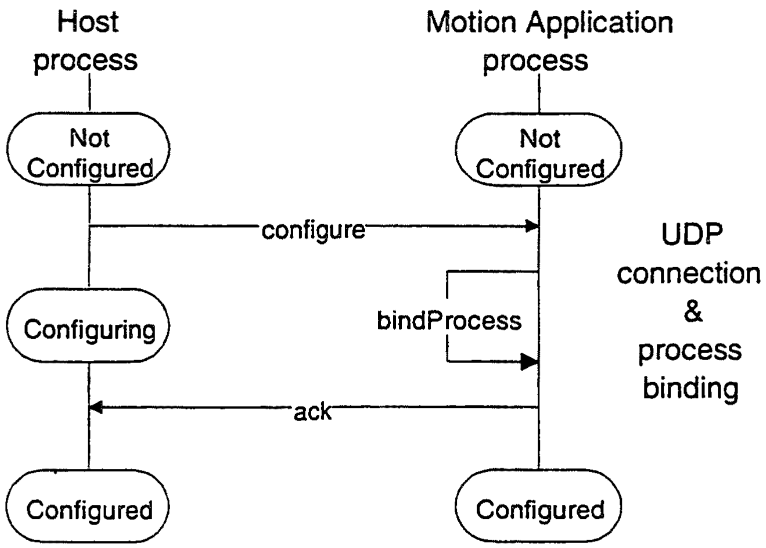


Figure 6-3 UDP Network initialisation sequence diagram

The *CONFIGURE* and *ACK* messages are specified in table 6-2, section 6.2.4.

6.2.7 Regular Host to Motion Real-time Computer Communication

For regular communication, the host periodically sends FCS datagrams to the motion real-time computer, each with the *HOST_TO_MOTION* header. This datagram contains information about the operational state of the motion system as demanded by the host, as well as vehicle dynamic data (vehicle acceleration data), which is needed by the motion cueing algorithm. For smooth motion cueing, the recommended update rate is 60 Hz approximately. The lower limit of the update rate is determined by a time-out error within the motion software and motion cueing latency requirements. For reasons of safety, the motion software will generate a time-out error if the delay between repetitive *HOST_TO_MOTION* datagrams exceeds TBD seconds (adjustable in configuration file 'motnode.dat'). As a result, the motion system will disengage.

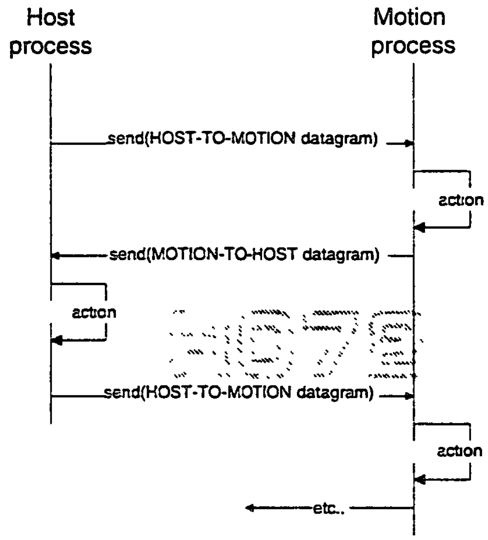


Figure 6-4 Communication scenario

For each *HOST_TO_MOTION* packet received, the motion real-time computer transmits a *MOTION_TO_HOST* datagram to the host, which contains status information of the motion system.

The FCS *MOTION_TO_HOST* and *HOST_TO_MOTION* datagram headers are specified in table 6-2, section 6.2.4. The contents of these datagram data area is specified in section 6.3

6.2.8 Closing a Communication Link with the Motion Real-time Computer

After a simulation session, the host can disconnect from the motion application by sending a *DISCONNECT* message. The UDP data transfer of buffers will be closed and the UDP socket of the motion software process will return to a listening state. This implies that the motion application is running in standby mode, ready to receive a new *CONFIGURE* message from a host that is trying to (re-) connect to the motion application. The FCS datagram for the *DISCONNECT* message is specified in section 6.2.4 table 6-2.

6.2.9 Supporting Software

FCS Control Systems has no standard software libraries available for the implementation of the host Ethernet communication task. For this the buyer should consult the libraries and documentation of their real-time operating system.

A simple PC based C++ Host-simulation program is available for in-house testing purposes. The customer can use this program as an example for:

- Setting up a communication link with the Motion real-time computer
- For transfer of data using UDP protocol

6.3 Motion Datagram Definitions

After a communication link between the motion real-time computer and host is established, the communication between the host and motion real-time computer is asynchronous and involves only two packet definitions. The host must send *HOST_TO_MOTION* datagrams to the motion real-time computer at a more-or-less constant frequency (ref section 6.2.7). In return, the motion software sends *MOTION_TO_HOST* datagrams containing status information. The datagram headers for these messages are specified in section 6.2.4, table 6-2. The *HOST_TO_MOTION* datagram data area is specified in the table 6-3.

Table 6-3 Specification of the *HOST_TO_MOTION* datagram data area

#	Name	Description	Units	Dimension
1	Control_Command	Motion command word		32 bit integer
2	Axbcg	Specific forces[c] in COG along X-vehicle body axis	m/s²	32 bit float
3	Aybcg	Specific forces in COG along Y-vehicle body axis	m/s²	32 bit float
4	Azbcg	Specific forces in COG along Z-vehicle body axis	m/s²	32 bit float
5	Pbdot	Angular acceleration about X-vehicle body axis	rad/s²	32 bit float
6	Qbdot	Angular acceleration about Y-vehicle body axis	rad/s²	32 bit float
7	Rbdot	Angular acceleration about Z-vehicle body axis	rad/s²	32 bit float
8	Pb	Angular velocity about X-vehicle body axis	rad/s	32 bit float
9	Qb	Angular velocity about Y-vehicle body axis	rad/s	32 bit float
10	Rb	Angular velocity about Z-vehicle body axis	rad/s	32 bit float
11	AxbcgBuffet	Buffet acceleration CG along X-vehicle axis	m/s²	32 bit float
12	AybcgBuffet	Buffet acceleration CG along Y-vehicle axis	m/s²	32 bit float
13	AzbcgBuffet	Buffet acceleration CG along Z-vehicle axis	m/s²	32 bit float
14	GFLswitch	Ground/Flight switch (0=ground, 1=flight)	m/s	32 bit integer
15	Vground	Groundspeed	m/s	32 bit float
16	Spare 1		-	32 bit float
17	Spare 2		-	32 bit float
18	Spare 3		-	32 bit float
19	Spare 4		-	32 bit float
20	Spare 5		-	32 bit float

[c] Specific Force = vehicle linear acceleration in X-, Y- or Z-direction, measured in vehicle body frame, including the gravity component along the X-, Y- or Z-axis.

As can be verified in table 6-3, the host packet contains both the motion command word and the vehicle dynamic data. The motion command word commands the operational state of the motion system. The behaviour of the motion system in response to the motion command word is determined by the motion state diagram, which is specified in section 6.4. The available motion control commands (MCOM) for the host to control the platform are listed in table 6-4.

Table 6-4 MCOM word values for Host-to-Real-time datapacket

MCOM Word Value	Definition	Remark
32 bit integer 0	EndOfTraining	Operational Command
32 bit integer 1	Disengage	Operational Command
32 bit integer 2	ReadyForTraining	Operational Command
32 bit integer 3	Engage	Operational Command
32 bit integer 4	Hold	Operational Command
32 bit integer 5	Reset	Operational Command
32 bit integer 6	ReleaseEndOfTrainingHold	Operational Command
32 bit integer 7	HardEndOfTraining	Only intended for host software development phase
32 bit integer 8	Break	

The vehicle dynamic data (vehicle accelerations) is input for the motion cueing model, which is part of the motion software. The vehicle accelerations are defined in a right-handed Cartesian reference frame with the origin in the vehicle's centre of gravity. The orientation of the axis, which are fixed with respect to the vehicle (i.e., a body frame), are the following:

- The z-axis is positive pointing downwards
- The x-axis is oriented in parallel to the vehicles longitudinal axis and is positive pointing forward
- The y-axis is positive pointing to the right

The *MOTION_TO_HOST* datagram data area is specified in the table 6-5.

Table 6-5 Specification of the *MOTION_TO_HOST* datagram data area

#	Name	Description	Units	Dimension
1	MSTATUS	Motion System Status	See Table	32 bit integer
2	MSTATE	Motion State Word	See Table	32 bit integer
3	MMODE	Motion Control Mode Word	See Table	32 bit integer
4	MUILOCK	Motion User Interlock Word	See Table	32 bit integer
5	MEMERGENCY	Motion Emergency Circuit Status	0 = closed, 1 = activated	32 bit integer
6	MRAMP	Motion Ramp Status		32 bit integer
7	MACTUATOR	Motion Actuator Channel Status	See Table	32 bit integer
8	MPOWER	Motion Power Supply Status	0 = ok, 1 = not ok	32 bit integer
9	MPNEUMATICS	Motion Pneumatics Status	See Table	32 bit integer
10	Spare1	Spare		32 bit integer
11	Spare2	Spare		32 bit integer
12	Spare3	Spare		32 bit integer
13	Spare4	Spare		32 bit integer
14	Spare5	Spare		32 bit integer
15	Spare6	Spare		32 bit integer

Dimension format: 32 bits 2's complement integer and IEEE floating point.

MSB = d31

LSB = d0

Information about the status words in the *MOTION_TO_HOST* status message is given in the tables below.

Table 6-6 MSTATUS word values in the *MOTION_TO_HOST* datagram

MSTATUS Word Bit Value	Definition
HEX 0000 0001	Controller & Model Time-out
HEX 0000 0010	I/O Card #1 Problem (Channels 1&2)
HEX 0000 0020	I/O Card #2 Problem (Channels 3&4)
HEX 0000 0040	I/O Card #3 Problem (Channels 5&6)
HEX 0000 0100	I/O Card #1 Not Found (Channels 1&2)
HEX 0000 0200	I/O Card #2 Not Found (channels 3&4)
HEX 0000 0400	I/O Card #3 Not Found (Channels 5&6)
Other bits	Not Defined

Table 6-7 MSTATE word values in the *MOTION_TO_HOST* datagram

MSTATE Word Value	Definition
32 bit integer 0	EndOfTraining (Off)
32 bit integer 1	Fail
32 bit integer 2	NonFail
32 bit integer 3	ForcedDisengaging
32 bit integer 4	Preparing
32 bit integer 5	Initializing
32 bit integer 6	ReadyForTraining
32 bit integer 7	Engaged
32 bit integer 8	Holding
32 bit integer 9	Disengaging
32 bit integer 10	Disengaged
32 bit integer 11	EndOfTrainingHold (Off-Hold)
32 bit integer 12	RampGoesUp
32 bit integer 13	RampGoesDown
32 bit integer 14	Aborting

The motion control can be operated in different modes:

- Normal mode, when under authority of the host;
- Test mode, under PC control or host control (not available).

Table 6-8 MMODE word bit values in the *MOTION_TO_HOST* datagram
(The normal operational value of MMODE is HEX 0000 0001)

MMODE Word Bit Value	Definition	Normal Operational Bit Value
HEX 0000 0001	Normal Mode	1
HEX 0000 0002	Test Mode PC Control (Not Used)	0
HEX 0000 0003	Test Mode Host Control (Not Used)	0

Table 6-9 MUILOCK word bit values in the *MOTION_TO_HOST* datagram
(The normal operational value of MUILOCK is HEX 0000 0000)

MUILOCK Word Bit Value	Definition	Normal Operational Bit Value (0=Interlock is Closed)
HEX 0000 0001	Door Interlock Open	0 when Interlock is Closed
HEX 0000 0002	Ramp Gate Interlock Open	0 when Interlock is Closed
HEX 0000 0004	Smoke Detector Alarm	0 when No Alarm
HEX 0000 0008	Heat Detector Alarm	0 when No Alarm

Table 6-10 MRAMP word bit values in the *MOTION_TO_HOST* datagram
(The normal operational value of MRAMP is HEX 0000 0003)

MRAMP Word Bit Value	Definition	Normal Operational Bit Value
HEX 0000 0001	Ramp is Up Switch A	1 when Up, else 0
HEX 0000 0002	Ramp is Up Switch B	1 when Up, else 0
HEX 0000 0004	Ramp is Down Switch	1 when Down, else 0
HEX 0000 0008	Ramp IR Interlock Open	1 when Ramp IR Interlock Open, else 0
HEX 0000 0010	Manual Override Selected	1 when Manual Override is Selected, else 0
HEX 0000 0020	Ramp Sensor Mismatch	0 when Ok, 1 when True
HEX 0000 0040	Ramp Raise Command Given	0 when False, 1 when True
HEX 0000 0080	Ramp Lower Command Given	0 when False, 1 when True

Table 6-11 MACTUATOR word bit values in the *MOTION_TO_HOST* datagram
(The normal operational value of MACTUATOR is HEX 0000 0000)

MACTUATOR Word Bit Value	Definition	Normal Operational Bit Value
HEX 0000 0001	Actuator #1 Fail	0 when Not Failed
HEX 0000 0002	Actuator #2 Fail	0 when Not Failed
HEX 0000 0004	Actuator #3 Fail	0 when Not Failed
HEX 0000 0008	Actuator #4 Fail	0 when Not Failed
HEX 0000 0010	Actuator #5 Fail	0 when Not Failed
HEX 0000 0020	Actuator #6 Fail	0 when Not Failed
HEX 0000 0100	Actuator #1 Non Fail	0 when Not Non-Failed
HEX 0000 0200	Actuator #2 Non Fail	0 when Not Non-Failed
HEX 0000 0400	Actuator #3 Non Fail	0 when Not Non-Failed
HEX 0000 0800	Actuator #4 Non Fail	0 when Not Non-Failed
HEX 0000 1000	Actuator #5 Non Fail	0 when Not Non-Failed
HEX 0000 2000	Actuator #6 Non Fail	0 when Not Non-Failed

Table 6-12 MPSLOGIC status word values in the *MOTION_TO_HOST* datagram
(The normal operational value of MPSLOGIC is HEX 0000 0008)

MPSLOGIC Word Bit Value	Definition	Normal Operational Bit Value
HEX 0000 0001	Main Power Fail	0
HEX 0000 0002	UPS Alarm	0
HEX 0000 0004	UPS Load on Mains	0
HEX 0000 0008	UPS Load on Inverter	1
HEX 0000 0010	UPS on Battery	0

Table 6-13 MPNEUMATICS word bit values in the *MOTION_TO_HOST* datagram
(The normal operational value of MPNEUMATICS is HEX 0000 0000)

MPNEUMATICS Word Bit Value	Definition	Normal Operational Bit Value
HEX 0000 0001	Pressure Low Signal Reservoir #1	0 when Pressure is Normal, 1 when Pressure is Low

6.4 Motion State Diagram

6.4.1 State Diagram for Normal Operation

The state diagram of the motion software for normal operation is depicted in figure 6-5. Failure conditions are handled by different states, which are presented in section 6.4.2.

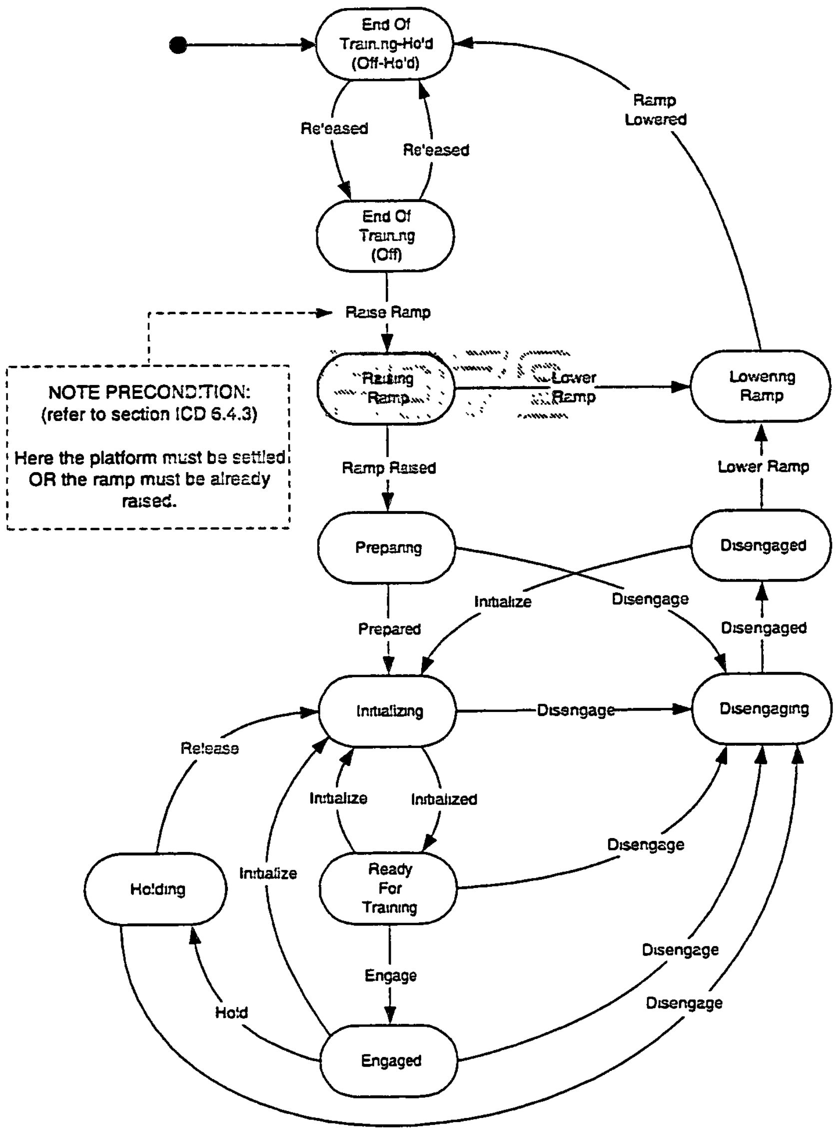


Figure 6-5 State diagram of the Motion Control Software for normal operation

The operational state of the motion system changes in response to commands received from the host, as part of the *HOST_TO_MOTION* datagram, and in response to internal generated events. Refer to section 5.3, table 5– for the list of available motion command words (MCOM) for the host.

The following operational states are defined:

- **EndOfTrainingHold**
  All actuators are mechanically braked. When the motion base is 'EndOfTrainingHold', the actuator encoders are not calibrated and therefore the actuator positions are in principle undetermined. In normal operational conditions, however, the motion base is down with all its actuators fully retracted, and resting in the buffers. The ramp is down (optional). The motion system is in settled position. In the 'EndOfTrainingHold' state, the motion system will not respond to any received MCOM with the exception of the 'ReleaseEndOfTrainingHold' command. This causes the operational state 'EndOfTraining' to become active.
- **EndOfTraining**
  All actuators are mechanically braked, as in the 'EndOfTraingHold' state. However, now the motion software is ready to accept motion command words (MCOM). The Event 'RampUp' is generated when the MCOM equals 'Disengage', 'ReadyForTraining' or 'Engage' (optional).
- **RaisingRamp (Optional)**
  When all settle switches of the actuators indicate that all actuators are fully retracted, the ramp is being moved up in preparation of engagement of the motion system. The 'RampRaised' event is generated when the 'Ramp up' switch is detected. Depending on MCOM the execution will continue in the 'Preparing' state or 'LoweringRamp' state.
- **Disengaged (Off)**
  All actuators are mechanically braked. In normal operational conditions, the motion system is settled. The actuator encoders are calibrated. An 'Initialize' event is generated when MCOM equals 'ReadyForTraining' or 'Engage'. A precondition is that the ramp-up switches are activated. A 'RampDown' event is generated when MCOM equals 'EndOfTraining'.
- **Preparing**
  The actuators are either slowly extended or retracted to settle switch position in order to calibrate the actuator encoders. This state is only executed from the 'EndOfTraining' state where the actuators are not calibrated. An 'Initialize' event is generated when all actuator encoders are successfully calibrated and MCOM equals 'ReadyForTraining' or 'Engage'.
- **Initializing**
  The Motion Cueing Algorithm is executed to line-up the motion filters with the vehicle dynamic data (vehicle accelerations) received from the host in the *HOST_TO_MOTION* datagram. A fader circuit is active to provide a smooth transition of the platform set point to an initial position. The platform kinematics software calculates the individual control signals for the actuators. The 'ReadyForTraining' event is generated when the platform reaches a stationary initial position and MCOM equals 'ReadyForTraining' or 'Engage'.
- **ReadyForTraining**
  The motion system is 'ReadyForTraining' when the platform position is initialized and stationary. This means that the platform is stationary in neutral position (all actuators mid-stroke) or a non-neutral initial position in case of dynamic initialization. An 'Initialize' event is generated when a change in the vehicle dynamic data requires an update of the platform initial position. In this case, the active 'ReadyForTraining' state autonomously falls back into the 'Initializing' state. An 'Engage' event is generated when MCOM equals 'Engage'.

- Engaged
  The motion platform responds dynamically to the aircraft dynamic input from the host. The Motion Cueing Algorithm computes the platform target position, velocity and acceleration and the Platform Kinematics Software calculates the individual position, velocity and acceleration signals for each actuator. A 'Hold' event is generated when a MCOM equals 'Hold'. A 'Disengage' event is generated by all states when MCOM equals 'Disengage'.
- **Holding**
  In the 'Hold' state, the vehicle dynamic input to the Motion Drive Algorithm is frozen. The Motion Drive Algorithm remains active but any changes of the host vehicle dynamic input are ignored. The Platform Kinematics Software calculates the individual position, velocity and acceleration signals for each actuator. A 'Release' event is generated when MCOM equals 'ReadyForTraining' or 'Engage'. In this case, the active state falls back into the 'Initializing' state. If the host dynamic vehicle input has not changed during freeze, the 'Initializing' state automatically switches to 'ReadyForTraining' and 'Engage' state. A 'Disengage' event is generated by all states when MCOM equals 'Disengage'.
- **Disengaging (internal state)**
  In the 'Disengaging' state, the platform is smoothly controlled to the settled position. Calibration information of each individual motion actuator is maintained. The 'Off' event is generated when the platform reaches the platform settled position and the settle switches indicate that all actuators are settled.
- **LoweringRamp (Optional)**
  When all settle switches of the actuators indicate that all actuators are fully retracted, the ramp is being moved to level egress/ingress position. The pneumatic support springs are depressurized. The 'EndOfTraining' event is generated when the 'Ramp down' switch is detected.

A more precise specification of the events that lead to state transients is given in table 6-14. The state transition mechanism as presented in the table 6-14 can be explained with the following scenario: assume that the motion operational state is 'EndOfTraining'. When from the host a 'ReadyForTraining' command is received, a Prepare event is raised which causes a state transition towards the Preparing state. In the Preparing state all actuator controllers will search for their settle switches. As soon as all actuator controllers have found their settle switch, the 'AllActuatorCalibrated' message is generated which causes the 'Initialise' event to be raised. The Initialise event causes a state transition towards the 'Initialising' state in which all actuators move to an initial, usually mid-stroke, position. When each actuator reaches the initial position, an 'AllActuatorsAtSet-point' and 'AllActuators-Stationary' message is raised. This means that the platform is elevated to the initial position and is stationary in that position (usually the so-called Neutral position). This raises the 'ReadyForTraining' event after which the state becomes 'ReadyForTraining'.

Table 6-14 Conditions for normal operation state transients

Current Motion Control State	Host Control Command	Internal Message	Event	New Motion Control State
EndOfTrainingHold	ReleaseEndOfTraining-Hold		Released	EndOfTraining (Off)
EndOfTraining (Off)	Disengage, ReadyForTraining, Engage		Raise Ramp	RaisingRamp
RaisingRamp	HardEndOfTraining, EndOfTraining		Lower Ramp	LoweringRamp
	Disengage, ReadyForTraining, Engage	Ramp is Up	Ramp Raised	Preparing
LoweringRamp	All	Ramp is Down	Ramp Down	EndOfTrainingHold (Off Hold)
	Disengage, ReadyForTraining, Engage			RaisingRamp

Current Motion Control State	Host Control Command	Internal Message	Event	New Motion Control State
Preparing	HardEndOfTraining, EndOfTraining, Disengage	All Actuators Calibrated	Disengage	Disengaging
	ReadyForTraining, Engage	All Actuators Calibrated	Prepared	Initializing
Initializing	EndOfTraining, Disengage		Disengage	Disengaging
	ReadyForTraining, Engage	All Actuators at Set-point All Actuators Stationary	Initialized	ReadyForTraining
ReadyForTraining	HardEndOfTraining, EndOfTraining, Disengage		Disengage	Disengaging
	Engage	All Actuators NOT Stationary	Initialize	Initializing
	Engage		Initialize	Initializing
Engaged	HardEndOfTraining, EndOfTraining, Disengage		Disengage	Disengaging
	ReadyForTraining		Initialize	Initializing
	Hold		Hold	Holding
Holding	HardEndOfTraining, EndOfTraining, Disengage		Disengage	Disengaging
	Release		Release	Initializing
Disengaging	All	Platform Settled OR All Actuators Calibrated Off	Disengaged	Disengaged (Calibrated Off)
Disengaged	HardEndOfTraining, EndOfTraining		Lower Ramp	LoweringRamp
	ReadyForTraining, Engage		Initialize	Initializing
Any State	Break	Any	EndOfTrainingHold	EndOfTrainingHold (Off Hold)

6.4.2 State Diagram for Failure Handling

The normal state diagram is valid for those cases where no failures have occurred, otherwise Motion Control will enter the 'Non-Fail' or 'Fail' state as shown in figure 6-6. In failure handling states, the states change in response to internal generated events. The motion command word MCOM received from the host as part of the *HOST_TO_MOTION* datagram, is ignored until a failure end state 'Non-Fail' or 'Fail' is reached. Then the host can reset the failure condition by sending a 'Reset' MCOM word.

The following failure handling states are available:

- **Forced Disengaging**

  This state is entered when during execution of a normal operational state a failure condition is detected, which does not require an immediate shut down of the motion system. In the 'ForcedDisengaging' state, all healthy actuators are retracted to their settled position. All failed actuators are mechanically braked in their current position. A 'Disengaged' event is raised when all settle switches are detected.
- **Non-Fail**

  The non-fail state is an 'error end-state'. The motion system has reached a stable end position and all actuators are mechanically braked. In principle, all healthy actuators are settled and all 'Non-Fail' actuators are mechanically braked in their current position. If the platform is settled, the ramp is moved to ingress/egress position (optional).

- **Fail**
  The fail state is an 'error end-state'. The motion system is in a static position with all actuators braked in the position when the fail condition occurred. Only if the platform is settled, the ramp is moved to ingress/egress position (optional).
- **Aborting**
  The Aborting state is mainly used to quickly settle the motion system in 'Emergency Abort' conditions such as when the ramp is moved down during simulation. The behavior of the motion system in this state is the same as in the 'ForcedDisengaging'. The only difference is that the actuator velocity and acceleration limits are set to higher values such that settling is achieved in less time.

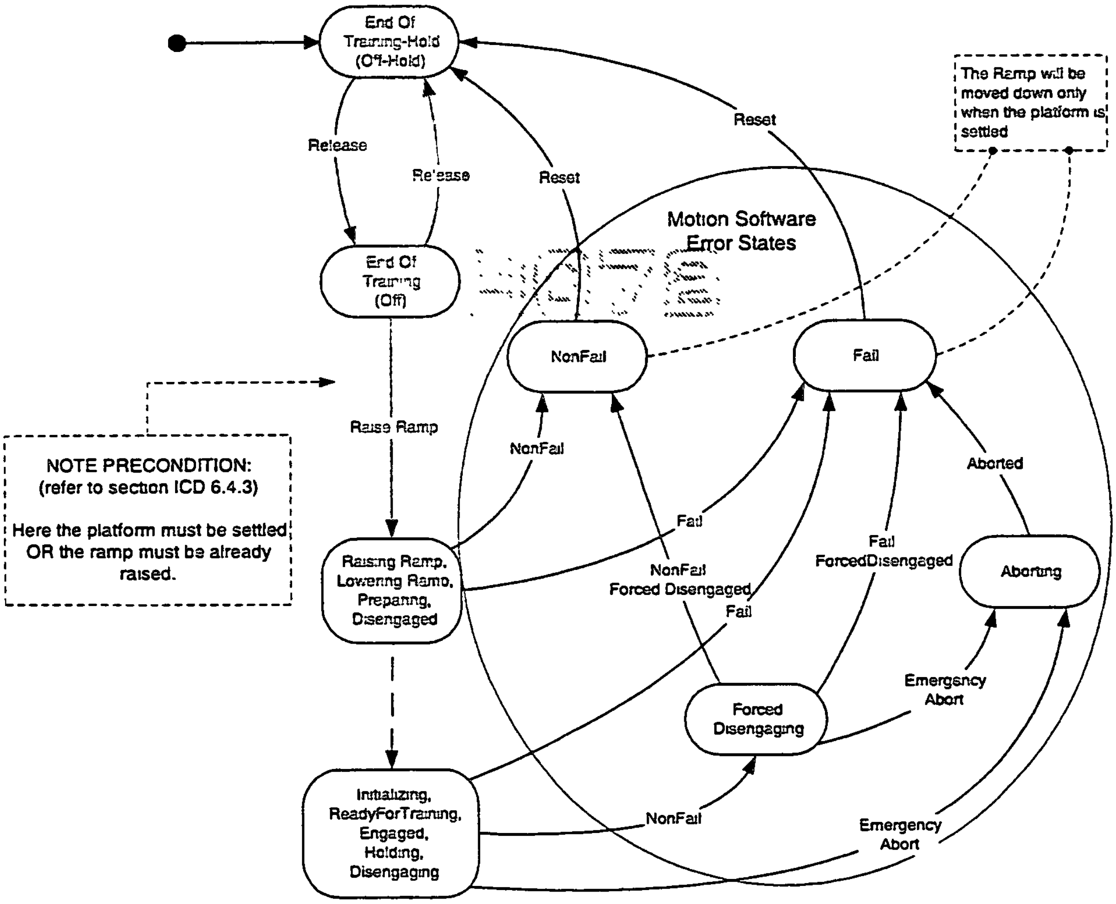


Figure 6-6 State diagram of the Motion Control Software for failure handling

A more precise specification of the events that lead to failure state transients is given in table 6-15.

Table 6-15 Conditions for failure handling state transients

Current Motion Control State	Host Control Command	Internal Message	Event	New Motion Control State
EndOfTrainingHold	Any	Any		
EndOfTraining	Any	Any		
LoweringRamp	Any	Ramp Sensor Mismatch	Non-Fail	Non-Fail
		Ramp Manual Override		
		Platform NOT Settled		
RaisingRamp	Any	Power Fail	Fail	Fail
		Emergency Circuit Open		
	Any	Host Communication Failure	Non-Fail	Non-Fail
		Pneumatic Pressure Low Ok		
		Smoke Detector Alarm		
		Heat Detector Alarm		
		Cabin Door Interlock Open		
		Platform Ramp Gate Interlock Open		
		Ramp Sensor Mismatch		
		Ramp Manual Override		
		Platform NOT Settled AND Ramp NOT Up (= Deadlock refer to section 6.4.3)		
Preparing,	Any	Power Fail	Fail	Fail
Disengaged		Emergency Circuit Open		
		Smoke Detector Alarm		
		Heat Detector Alarm		
		Ramp Sensor Mismatch		
		Ramp NOT Up		
		Ramp Manual Override		
	Any	Host Communication Failure	Non-Fail	Non-Fail
		Pneumatic Pressure Low		
		Smoke Detector Alarm		
		Heat Detector Alarm		
		Cabin Door Interlock Open		
		Platform Ramp Gate Interlock Open		
		One or more Actuators in NonFail State		
		One or more Actuators in Fail State		
Initializing,	Any	Power Fail	Fail	Fail
ReadyForTraining		Emergency Circuit Open		
Engaged	Any	Host Communication Failure	NonFail	ForcedDisengaging
Holding		Pneumatic Pressure Low		
Disengaging		Cabin Door Interlock Open		
		Platform Ramp Gate Interlock Open		
		One or more Actuators in NonFail State		
		One or more Actuators in Fail State		
	Any	Smoke Detector Alarm	Emergency Abort	Aborting
		Heat Detector Alarm		
		Ramp Sensor Mismatch		
		Ramp NOT Up		
		Ramp Manual Override		

Current Motion Control State	Host Control Command	Internal Message	Event	New Motion Control State
ForcedDisengaging	Any	Power Fail Emergency Circuit Open	FailForcedDisengaged	Fail
	Any	Smoke Detector Alarm Heat Detector Alarm Ramp Sensor Mismatch Ramp NOT Up Ramp Manual Override	Emergency Abort	Aborting
	Any	All Actuators that are Normally Operational are Settled	NonFailDisengaged	NonFail
Aborting	Any	Power Fail Emergency Circuit Open	Aborted	Fail
	Any	All Actuators that are Normally Operational are Settled	Aborted	Fail
Non-Fail	Reset	Any	Reset	EndOfTrainingHold
Fail	Reset	Any	Reset	EndOfTrainingHold
Any State	Break	Any	EndOfTrainingHold	EndOfTrainingHold

6.4.3 Deadlock in the Automatic Control of the Ramp; Preconditions for Start of the Motion System

A deadlock in the automatic control of the ingress/egress ramp by the Motion Control Software occurs when the 'EndOfTrainingHold' state is active while the platform is not settled AND the ramp is not up. When motion consent is given and a 'ReadyForTraining', 'Engage' or 'Disengage' command is received from the host, the motion software will generate a 'RaiseRamp' event. The then activated 'RaisingRamp' state will generate a 'Non-Fail' error-event because the ramp cannot be moved since the motion platform is not settled. Ignoring this might cause a collision between ramp and platform. Because of the same reason, the subsequent Non-Fail error state will not attempt to lower the ramp because the platform is not settled. Hence the situation is not altered.

The only way to get out of this situation is by manually moving the ramp up after verifying that collisions between ramp and platform are not possible.

Note: Ramp is optional.

Control Systems

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TABLE OF CONTENTS

1. INTRODUCTION

This *System Design Report* describes the Electric Motion system and the safety interlock system for the the E-Cue 636-3500 Motion System for AMST.

All interfaces are described in the *Interface Control Document (ICD)*.

2. E-CUE 636-3500 MOTION SYSTEM DESCRIPTION

The motion system for the the E-Cue 636-3500 Motion System for AMST comprises of the following mayor mechanical, electrical and software components (see figure 2-1):

- Six electro mechanical actuators
- Floor plates, joints and upper frame
- A pneumatic subsystem consisting of:
  - Three low-pressure pneumatic springs, which carry the static weight of the platform during platform operation (only one is shown in figure 2-1).
  - A compressor
  - A pneumatic reservoir (not shown)
- A Motion Control Cabinet (not shown) housing the:
  - Motion Power Electronics
  - Motion Control Panel
  - Motion Real-time Computer and the maintenance computer
- The FCS Motion Control Software, which is executed by the Motion Real-time Computer and drives the motion platform in response to simulated vehicle motion, ordered platform motion and/or ordered actuator motion.
- The graphical *Motion Explorer* software (Windows 95/98/NT/2000), which is used for maintenance, troubleshooting and testing purposes.

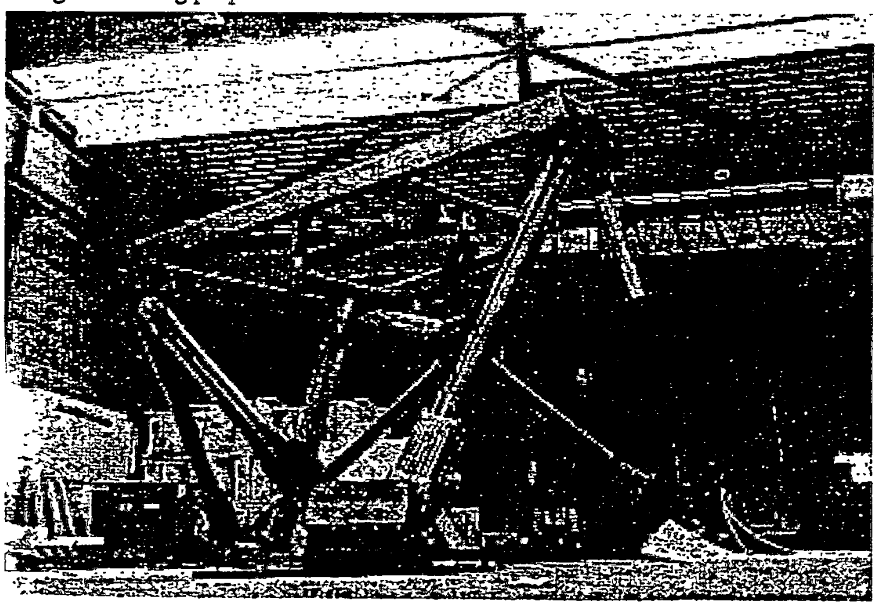


Figure 2-1 Picture of the E-Cue 636-3500 motion system

2.1 Motion Base Frame, Simulator Platform and Universal Joints (MFJ)

The motion system is attached to the floor of the simulator room by means of three separate floor pads. On each of these floor pads, a joint assembly is mounted for the electric actuators and the pneumatic support springs. The floor pads are bolted to the concrete floor by means of 8 M24 chemical plugs. A further specification and drawings are given in the ICD.

The joints of the electromechanical actuators include silent blocks in order to avoid the propagation of noise and high frequency vibrations to the cabin.

2.2 Motion Electric Actuator (MAC)

The E-Cue 636-3500 actuator has a 900 mm stroke between buffers and comprises:

- A stiff structure of steel telescopic tubes with low friction sliding bearings.
- A ground ball screw with long lead for high linear speed at low revs and minimisation of noise. The ball screw is lubricated by grease.
- A brushless DC servomotor including a tachometer and resolver.
- A flexible coupling connects the motor to the screw shaft. There is no transmission like a toothed belt, chain or gear wheels that needs maintenance and causes noise.
- An inductive settle switch. The actuator position is derived (in the Motion Real-time Computer) from a resolver derived encoder signal and the settle switch.
- A mechanical brake to hold the actuator in position after a failure or emergency stop (freeze).

The motor and amplifier are sized to hold the system stationary in every possible position for an infinite time (the motor torque is below its specified continuous torque level). The motor peak torque ensures that in every possible position, sufficient acceleration or deceleration is possible.

2.3 Motion Control Cabinet (MCB)

The Motion Control Cabinet consists of one cabinet, which contains all motion electronics. A photo of the Motion Control Cabinet is given in figure 2-2. The components of the MCB are discussed in the next subsections.

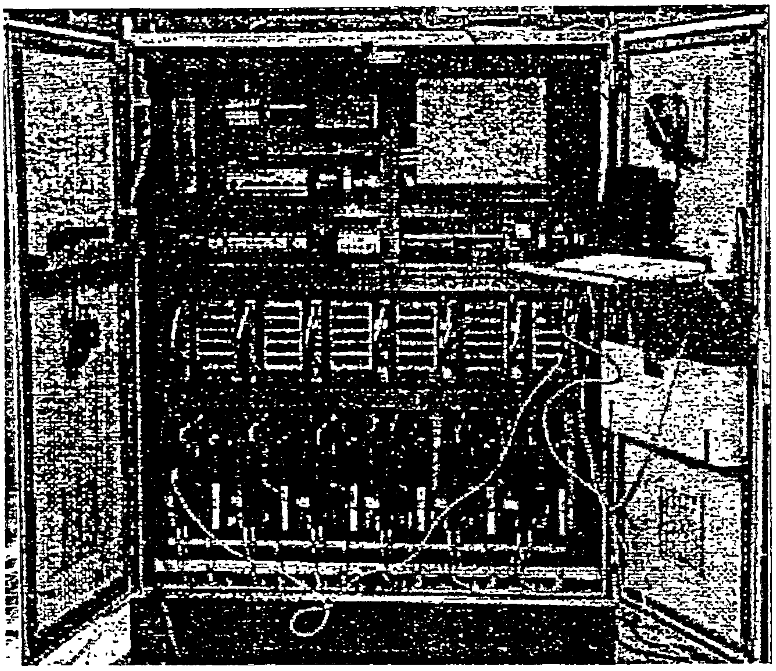


Figure 2-2 The Motion Control Cabinet

2.3.1 External Interfaces

Figure 2-3 shows the components within the Motion Control Cabinet and it's internal and external interfaces. The components of the cabinet are listed in the following subsections.

The external interfaces are the following:

- 3 phase 380 ~ 480 V + neutral 50/60 Hz mains power connection
- Modem connection
- Ethernet 100 Tbase T, RJ45 connector
- Ramp control data (optional):
    - Ramp up/down switches
    - Ramp control signal
- Discrete inputs:
    - User interlocks (door switches, pressure pads etc) (optional)
    - Emergency stop interlock (emergency stop buttons)
    - Motion Remote On/Off
- Discrete outputs:

   - Visual warning signals
   - Emergency stop interlock
   - Motion system settled
   - Access ramp down (optional)
   - Access ramp up (optional)
- Actuator control:
   - Electric motor current
   - Actuator sensor signals

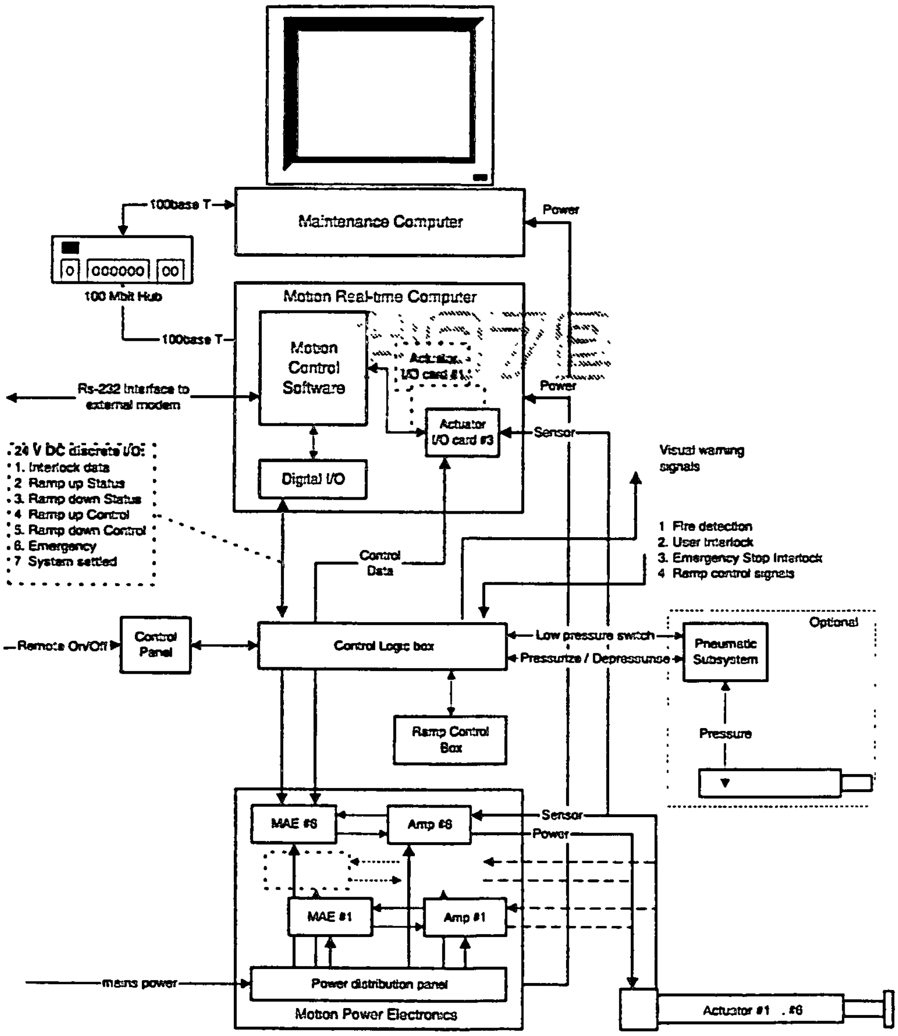


Figure 2-3 The Motion Control Cabinet: internal and external interfaces

Refer to the ICD for a further specification of the interfaces.

2.3.2 Motion Power Electronics (MPE)

The Motion Power Electronics unit contains electronic equipment and components. The primary components are.

1. Motion Actuator Electronics I/F (6x)
2. Amplifiers (6x)
3. Power Distribution Panel
4. Capacitor units (6x)

Furthermore, connectors and wiring are included for:

- User interlock circuit
- Emergency button circuit
- Actuator motors
- Actuator sensors (tachometer, resolver, settle switch)

The maximum length for the actuator motor cables is < 15 meter.

A description of these components in some more detail is given below:

1. The Motion Actuator Electronics (MAE) consist of the following components:
   - I/O interface
   - Amplifier controller
   - Operational and safety logic functions

   The logic functions implemented within the MAE unit control the operational state of the actuator channel. The following states are defined:
   - *Off*
   - *Brake*
   - *Active*
   - *Auto Retract*

   A specification of these states is given in section 3.6.1 and the state transients are specified in figure 3-1.
2. The amplifiers are COTS parts, including bleed resistors and capacitors. The amplifiers have their own power supplies.
3. The Power Distribution Panel has as its main function to switch on the amplifiers (one-by-one). Furthermore, the Power Distribution Panel feeds the computers, the MAE I/F's and others.

2.3.3 Control Logic Part

This part interfaces between the digital I/O card and various hardware, as there are:

- Control panel
- Ramp control (optional)
- Pneumatic subsystem
- User interlocks
- Emergency stop interlock

- Visual warning
- Fire detection

2.3.4 Motion Control Panel (MCP)

The Motion Control Panel comprises:

- Control panel key switch with four positions: *Auto Retract*, *Power*, *Standby* and *Remote*.
- Discrete I/O input for remote On/Off command (at the backside of the panel)

The control panel key switch controls the 6 three phase 380 ~ 480 V contactors in the power supply. It also switches the power to the Motion Real-time Computer and maintenance computer. It is possible to connect the Motion Real-time Computer and maintenance computer to a separate mains voltage.

Switching to *Standby* position during operation leads to:

- The main contactor is disabled
- All amplifiers are disabled
- Actuator brakes are enabled

The control panel switch can be set to *Remote* permanently in which case the system can be switched to *Power* and *Standby* by using a contact at the host computer side.

When the control panel switch is in *Auto Retract* position, and there is no heartbeat signal, the actuators are retracted with constant velocity until the settle switches are reached. This can be used to retract the motion system to settled position when the Motion Real-time Computer is not operational.

2.3.5 Motion Real-time Computer (MRC)

The Motion Real-time Computer controls the motion system and actuators. The MRC comprises:

- Industrial PC with > 500 MHz Intel Pentium III processor board, > 1GB Hard disk, floppy drive and 64MB RAM
- Analog/digital Interface board to each MAE I/F
- Digital interface board to the Motion Power Electronics (MPE) and other logic
- 100Mbit Ethernet interface board to the 100 Mbit hub
- High speed modem card

A PC running the *Motion Explorer* can interface with the MRC either using the Ethernet or RS-232 interface. The modem card is added to support remote sessions of the *Motion Explorer* (ref. Section 2.5.5).

An overview of the interfaces of the Motion Real-time Computer is given in figure 2-3.

2.3.6 Maintenance Computer

The Motion Cabinet contains a maintenance laptop. The maintenance computer can be used for the following purposes:

- To execute system tests, e.g. the test of the Factory Acceptance,
- To monitor the state of the motion system while the system is in operation,
- To assist in the tuning of the motion software and servo loops,
- To assist in trouble shooting activities.

The maintenance computer interfaces with the Motion Real-time Computer by means of the Ethernet 100Mbit connection. Main power is obtained from the Power Distribution Panel.

2.3.7 Ethernet Hub

When necessary, a 100Mbit Ethernet Hub is available for interface between the Motion Real-time Computer and simulator host. The Hub can interface with UTP.

2.4 Motion Pneumatic System (MPN)

The Motion Pneumatic System consists of the following elements:

- Three pneumatic cylinders
- A compressor
- One air tank of 270 liter
- Hoses to the air tank
- A pressure switch to detect possible failures in the pneumatic system

The pneumatic cylinders are connected to the base frame and the upper frame. An example drawing of the pneumatic springs and their main dimensions is shown in figure 2-4.

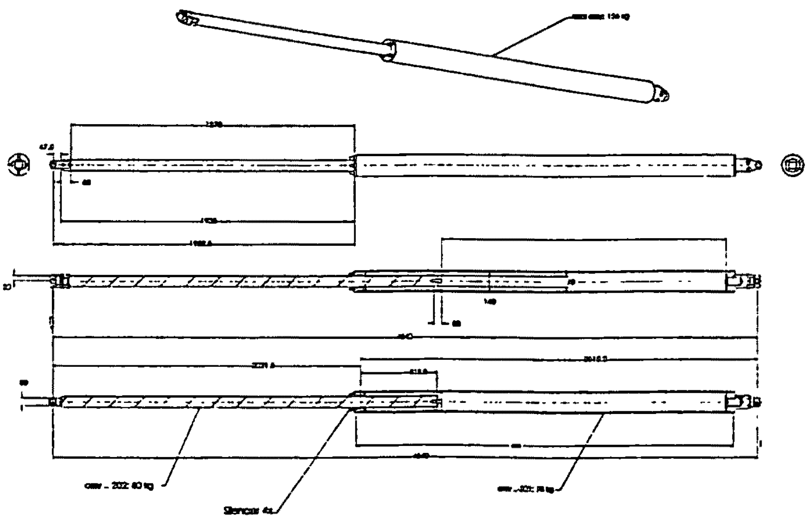


Figure 2-4 Example drawing of pneumatic support springs (E-Cue 660-6000 Motion System)

The MPN is a low-pressure, passive system. The purpose of the pneumatic subsystem is to support the static weight of the cabin during operation such that only the dynamic motion (acceleration and deceleration) of the cabin is driven by the electric actuator. Advantages are:

- A lower maximum motor torque is required
- The energy consumption is considerably reduced
- The total noise level is lower
- Actuator life increases

The logic that drives this subsystem is implemented in the Motion Power Electronics. Hoses connect the cylinders to an expansion tank to reduce pressure variation. Possible air leakage is compensated by a small compressor that is connected via a pressure control valve to the tank.

FCS has chosen for separate pneumatic spring supports instead of a solution where the pneumatic spring is integrated in the electro mechanical actuator. Advantages are:

- The pneumatic cylinder is a COTS item that can be supplied locally anywhere in the world
- Possible failure of a pressure seal does not lead to the time consuming task of exchanging and dismantling the electro mechanical actuator. The separate pneumatic spring can be exchanged in 15 minutes.
- The design of the electro mechanical actuator remains as straightforward as possible. Consequently there is less chance of failure.

FCS has chosen for an air-pressured system with compressor instead of a solution with 'filled for life' hydro pneumatic springs (that is either separate or integrated with the electro mechanical actuator). Advantages are:

- The pressure, and therefore the compensating force on the moving mass, is always guaranteed without any maintenance. In a hydro pneumatic strut the pressure drops due to loss of nitrogen. Hydro pneumatic struts need regular pressure checks, and refills with nitrogen. A too low pressure can lead to overload of the electric motors and decrease the performance.
- Changing payload conditions can be met by simply adjusting the pressure on the pressure control valve.

2.5 Software

2.5.1 Overview: Software Components and Interfaces

The software delivered with the motion system consists of two components. The most important component is the FCS Motion Control Software (FMCS or Motion Software), which controls the motion system and runs on the Motion Real-time Computer. This software interfaces with the host computer by means of an Ethernet interface using the TCP/IP or UDP protocol.

For maintenance, testing and trouble-shooting purposes, the *Motion Explorer* Windows 95/98/NT/2000 application is delivered with the system. This application runs on a standard PC and can connect with the Motion Real-time Computer by means of an Ethernet, RS-232 or by modem connection.

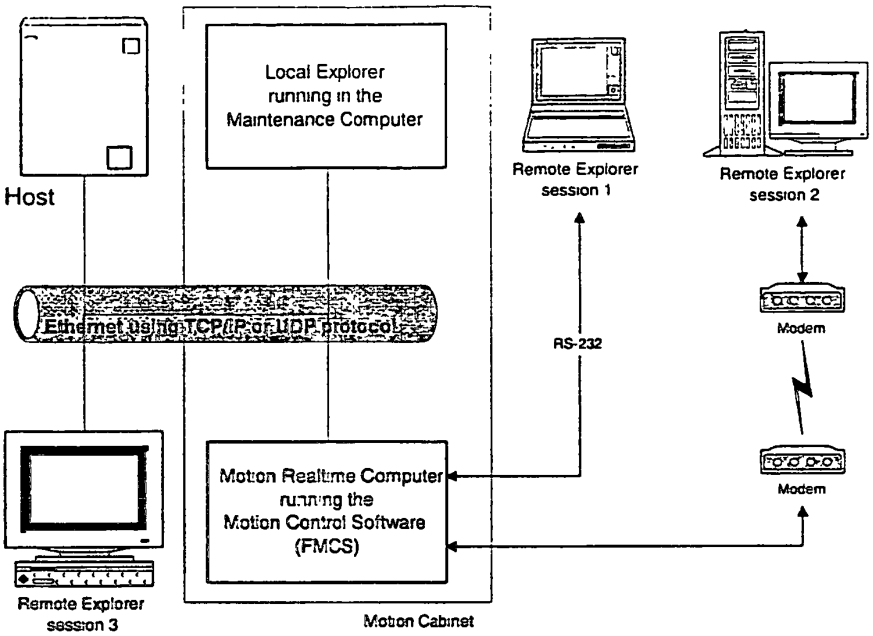


Figure 2-5 The Motion Real-time Computer connected with the host by means of Ethernet and serving three *Motion Explorer* sessions (example)

Within the data field of the TCP/IP or UDP protocol, a simple protocol is defined which allows the host computer and any *Motion Explorer* session to access special services of the FCS Motion Software or its underlying software modules.

In its simplest usage, this protocol allows communication between the host and Motion Real-time Computer as a constant stream of standard command/data packets sent to the Motion Real-time Computer, and a stream of standard status packets sent back to the host in response. When used to its fullest potential, the protocol supports integration of the motion system into the simulator diagnostics and operator software.

2.5.2 The FCS Motion Control Software (FMCS)

The FCS Motion Control Software (FMCS) in short controls the motion system. In more detail, the tasks of the FCS Motion Control Software are the following:

1. Operation of the state of the motion system at system level in response to commands received from the host simulation and other internal and external stimuli. The state diagram for normal operation is specified and explained in section 3.6.2.

2. Execution of the FCS Motion Drive Software (FMDS) during dynamic simulation (i.e., during *Engaged* state). The Motion Drive Algorithm translates the simulated vehicle accelerations and velocities into platform position, velocity and acceleration set points.

3. Execution of the Motion Actuator Control software (servo loops), which controls the actuator such that the demanded platform motion is realized.

4. The execution of several monitoring and safety functions at system and channel level.

5 Reporting status, warning and error messages to the host and *Motion Explorer* sessions.

6. Execution of test-modes at platform level or at actuator level.

The Motion Real-time Computer interfaces with all subsystems of the motion system as is shown in Figure 2-2, section 2.3.1. The Motion Software continuously monitors all motion system components. When the behavior of a component is detected outside specified tolerances, either a warning or an error message is issued to the host computer. In case of an error condition, appropriate actions are undertaken. For a further description and specification of failure handling refer to section 2.6 and 3.6

The FCS Motion Control Software makes a number of services available to the host and *Motion Explorer* (refer to section 2.5.5) and can handle multiple requests for these services while performing the above time-critical tasks.

Finally, the Motion Software performs a *Hardware Confidence* test at start-up.

2.5.3 The FCS Motion Drive Software (FMDS)

The FCS Motion Drive Software is a model within the FCS Motion Control Software. When the motion system is in *Engaged* state, the FCS Motion Drive Software (FMDS) transforms the real vehicle motion, provided by the host computer, into accelerations, velocities and positions of the moving platform. The algorithm is driven by the simulated vehicle linear accelerations, vehicle rotational acceleration and velocities, and linear buffet accelerations (used for vibrations; optional). Other control variables may be added depending on the training task and maneuvers to be simulated.

While the motion platform is designed to provide a large usable kinematic motion envelope (large single DOF and combined DOF excursions), the Motion Drive Algorithm is designed to maximize the Dynamic Motion Envelope of the platform. The Dynamic Motion Envelope in this respect refers to the collection of actual vehicle maneuvers that the platform can represent in a way judged by a human pilot as realistic to the vehicle. The software contains a number of features that make the motion system feel 'larger' than it really is.

The main features of the FCS Motion Drive Software are the following:

- Complementary Low Frequent and High Frequent motion filters (increases dynamic motion envelope).
- Specific Force Error correction.
- Adaptive motion cue Attenuation and Washout (increases dynamic motion envelope).
  This feature allows sensitive tuning for the small and average dynamic vehicle inputs that occur 95% of the time. The filters automatically adapt to rare large and violent dynamic inputs.
- Dynamic Offset;
  This feature allows the platform to be moved to an optimal position to prepare for large and violent occasional vehicle inputs. Example: platform movement to full aft position prior to full stop (end of braking effect).
- Advanced Platform Kinematics (increases Dynamic Motion Envelope).
  This feature allows all low frequent platform rotations to take place about a non-fixed rotation point, which is optimal from a kinematic viewpoint. Only high frequent rotations take place about the pilot eye-point.
- The above features and other parts of the software can be tuned to the dynamics of the vehicle by more than 260 categorized tuning parameters which are collected into a named tuning set.
- Support of multiple tuning sets.
  The software supports multiple tuning sets, for example to support different driving conditions and training tasks.

- Support of multiple Motion Cueing models.
  The software supports multiple Motion Cueing models, for example to support different driving conditions and training tasks.

The FCS Motion Drive Software makes a number of services available to the host and *Motion Explorer* (refer to section 2.5.5):

- Selection of the active tuning set and active Motion Cueing Model.
- Duplication of a tuning set, changing tuning parameters and storing tuning sets
  (as an option, password protected)

The FCS Motion Drive Software can be expanded by FCS Control Systems to support user-defined special effects.

2.5.4 The Motion Actuator Controller (MACS)

The Motion Actuator Controller (MACS) is a module within the FCS Motion Control Software. There is a Motion Actuator Controller module for each actuator.

The Motion Actuator Controller module controls the state of one actuator channel and executes a Servo Loop Model. Generally, the Motion Actuator Controller contains only one Servo Loop Model that is configured by one tuning-set. However, the use of multiple Servo Loop Models is supported as well as multiple tuning sets per Servo Loop.

The Servo Loop Model drives an actuator using position, velocity and acceleration set points as commanded by the FCS Motion Control Software. Moreover, it contains a dynamic acceleration and velocity limiter, which reduces the allowed level of accelerations and velocities when the actuator is near full extension or retraction.

Continuously, the performance of an actuator is checked against a performance baseline in order to detect errors or symptoms of errors. When the behavior of the actuator is detected outside specified tolerances, either a warning or an error message is issued to the host computer and any active *Motion Explorer* session. In case of an error condition, appropriate actions are undertaken.

Each Motion Actuator Controller module makes a number of services available to the host and any active *Motion Explorer* session (refer to section 2.4.5). Examples are:

- Duplication of an servo-loop tuning set, changing tuning parameters and storing tuning sets (password protected)
- Monitoring of hardware signals

The Motion Actuator Controller module interfaces with the actuator hardware (amplifier and actuator sensors) by means of a dedicated I/O card. This card has the following interfaces with the actuator electronics and sensors:

- Analog velocity set point to the PWM servo amplifier (via the MAE I/F-card)
- Analog tacho signal
- Digital encoder signal
- Digital settle switch signal
- Digital amplifier command and status signals

2.5.5 FCS *Motion Explorer* Software

The *Motion Explorer* is a Graphical User Interface (GUI) for the Motion Control Software and motion system and can be used for the following purposes:

- Factory and on-site acceptance tests
- Monitoring and diagnostics
- Motion tuning

The *Motion Explorer* is a stand-alone Windows 95/98/NT/2000 application. Figure 2-5 shows that this user interface is either executed from the maintenance computer, which is installed in the Motion Control Cabinet, or from a customer supplied external/remote PC, which is linked to the Motion Real-time Computer through a Ethernet, RS-232 or modem connection. This architecture supports remote diagnostics with multiple Explorer sessions active at the same time, which offers the possibility for synchronous local and remote troubleshooting activities.

After start-up, the Explorer must *Log In* to the FMCS application using one of the communication interfaces. After the connection is established the FMCS Application uploads its list of components to the *Motion Explorer*. The Explorer is then capable to display this information in two different views, the *Schematic View* and the *Browse View*, which can be selected at will by the user.

The *Schematic View*, as depicted in figure 2-6, shows a block diagram of the components of the motion system and is especially designed for local maintenance personnel. All of the system components shown have tabulated dialogs that can be activated by simple point-and-click mouse actions. These dialogs give detailed information about the status of the component and present links to underlying components, which have their own dialogs.

For easy trace ability in case of system errors, the background color of each component is used to encode the failure state of the component. Green encodes a component within operational limits while flashing red indicates that a failure has occurred. Selecting these objects with the mouse will give information about the state of the selected object including warning and error messages.

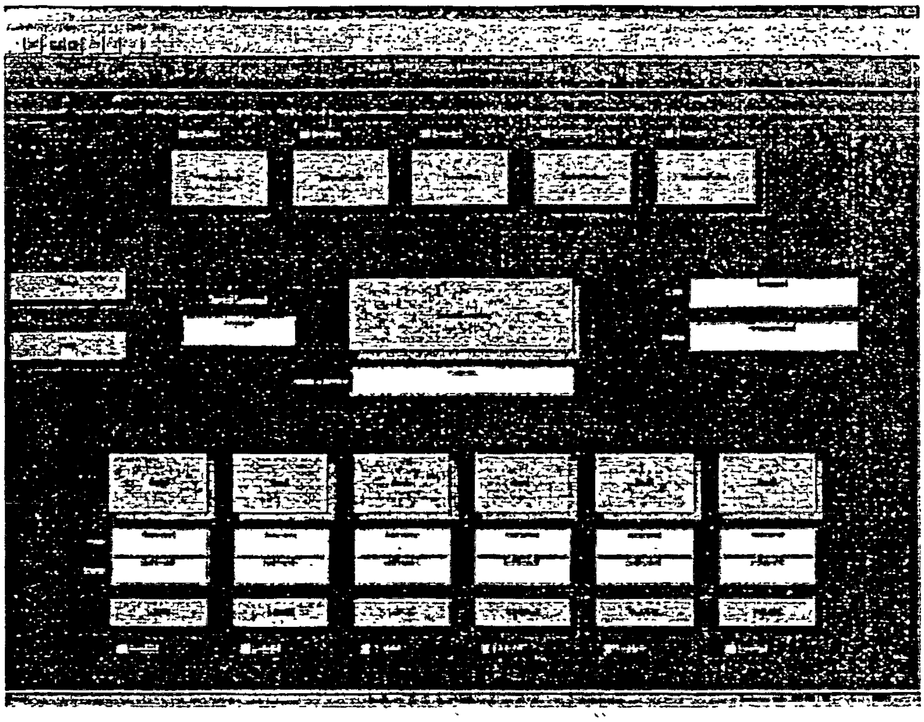


Figure 2-6 The *Schematic View* of the *Motion Explorer*

A special component is the *Host* component as shown in figure 2-6. Selecting this component brings-up a dialog, which enables execution of test-modes, used for testing and factory acceptance.

As an alternative to the *Schematic View*, the Explorer offers an in-depth *Browse View* as shown in figure 2-7. The visual appearance of the *Browse View* is similar to the Windows 95 file explorer. The left panel contains the browse tree that hierarchically lists all software and hardware components such as:

- Actuators
- Controllers
- Models
- States
- Variables
- Parameters
- Signals to- and from the hardware

The right panel shows the contents of any selected component in the left panel. All of the dialogs offered by the *Schematic View* are still accessible by clicking on the appropriate components within the browse tree.

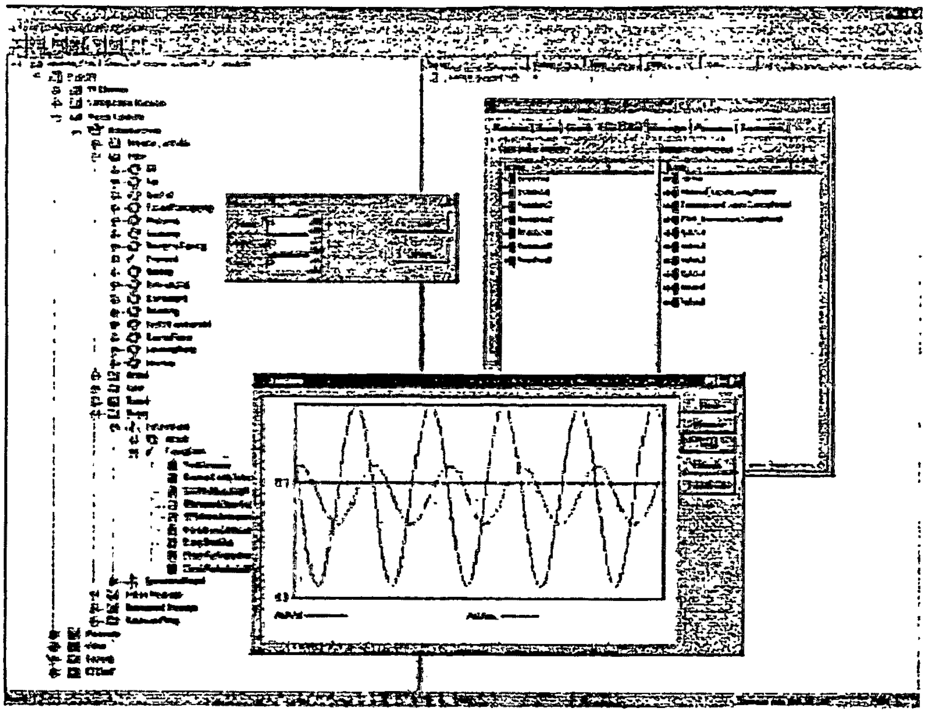


Figure 2-7 The in depth *Browse-View* of the *Motion Explorer*

The *Browse View* offers a more technical and more detailed view of the motion system and its components. The user can start browsing at the top-application level and browse all the way down to the pin-level of the hardware I/O cards. At any level, variables and signals can be viewed numerically or graphically using a sampling window. Model parameters can be selected and permanently changed, which is an essential feature necessary for tuning of the motion cueing model and the servo control loops. To safeguard the configuration of the simulator when in operation, all parameter changes are protected by means of a password mechanism.

2.6 Internal Fault Detection and Handling Functions

The motion system software and hardware contain a number of fault detection and handling functions. As indicated by figure 2-8, these functions are distributed over motion software components, components of the motion power electronics and the motion actuator.

A further specification of these components and their safety functions is given below:

1. Motion Controller
   - Limiting of host input signal amplitude
   - Limiting of demanded platform motion to physical limits
   - *Motion Software OK* heartbeat signal, which is only updated when the Motion Control Software is running normally.
   - Actuator Dynamic Response Check. In this check, the actuator position and velocity is compared with the computed command signal. When the actuator response is outside tolerances the *Actuator control Loop OK* signal is removed.

2. Actuator Controller
   - Limiting of demanded actuator dynamic state to predetermined limits
   - Dynamic Limiting of the command signal based on the current actuator position and velocity with respect to the actuator end-stops.
   - Consistency crosscheck between the encoder, tacho signals. When the check fails, the amplifier enable signal is removed and the MAE goes to *Off/Abort* state (ref. section 3.6.1).
   - Actuator Dynamic Response Check. In this check, the measured actuator position and velocity is compared with the commanded actuator position and velocity. When the actuator response is outside tolerances the amplifier is disabled and the MAE goes to *Off/Abort* state (ref. section 3.6.1).

3. Motion Actuator Electronics (MAE)
   - The safety logic checks for the amplifier enable signal, and checks whether the Motion Real-time Computer (*Motion S/W OK* signal), Actuator Controller (*Actuator Control Loop OK* signal) are within operational limits. Based on these inputs and the Emergency Stop Interlock signal, the Motion Safety Logic determines the operational state of the MAE unit. The MAE is either in *Active* state, allowing the Motion Control Software to operate the actuator, *Off/Abort* state where the electric brakes are engaged or in *Auto Retract* state when there is a Failure of the Motion Real-time Computer. For further elaboration of these states refer to section 3.6.1.
   - The MAE unit enables the amplifier by three different signals for redundancy (*Fault reset*, *Limit* and *Enabled*). In case of MAE failure, the chance that the amplifier is still active is therefore minimized. Furthermore, the MAE receives three signals from the computer to be enabled (*Amplifier enable*, *Motion Software OK* and *Actuator Control Loop OK*).

4. Amplifier
   - In normal operational states of the Motion Power Electronics, the input signal for the amplifier is obtained from the MAE. In error handling states the external input can be switched to an internal signal representing a constant velocity command signal that results in slow actuator retraction.

When working together, the safety functions only allow the motion system to be operational when the behavior of the system is within specified tolerances. If the system is outside tolerances, the motion is disengaged.

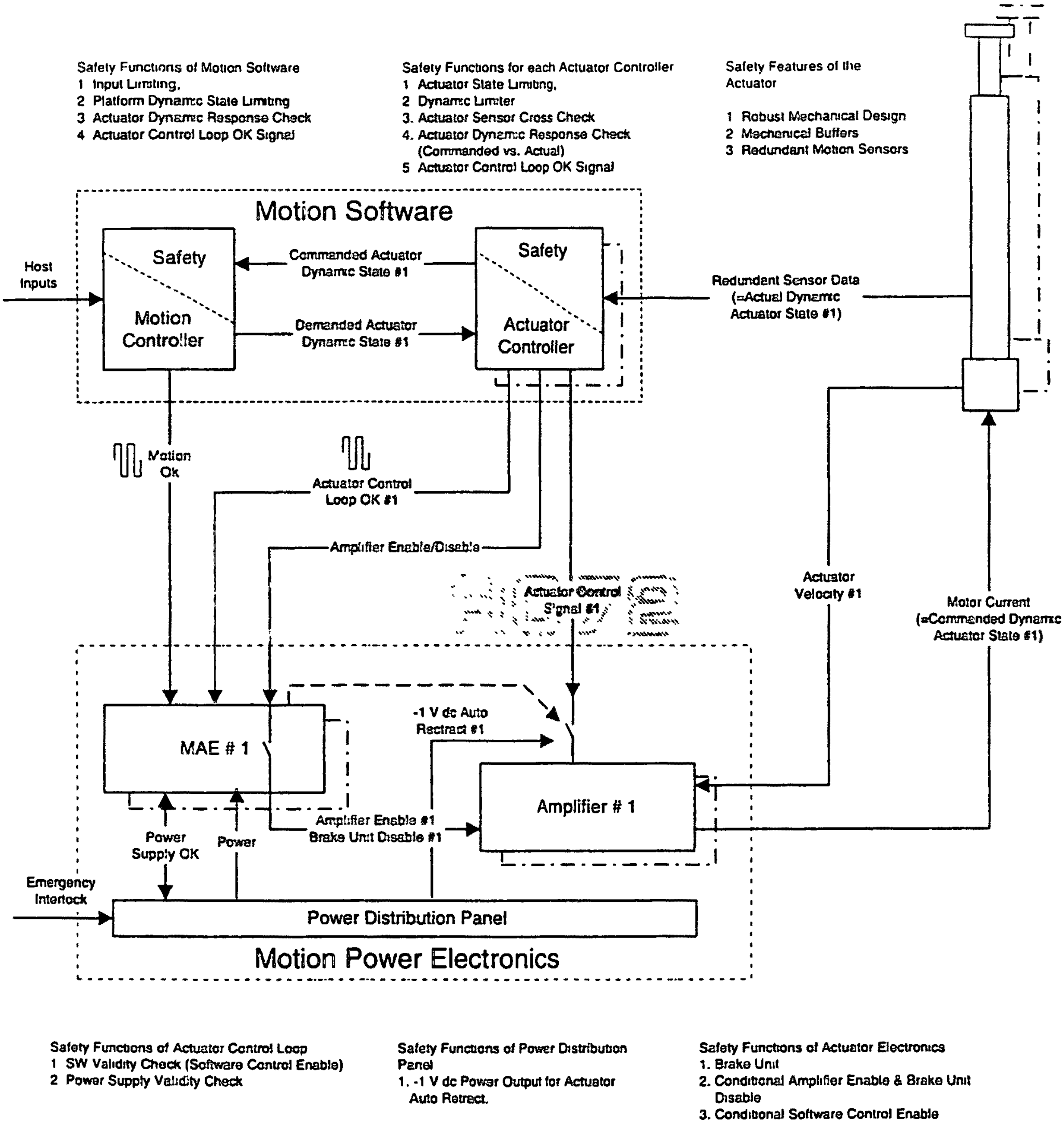


Figure 2-8 Fail detection and handling functions

2.7 User Interlocks

The motion system can be equipped to support multiple user interlock circuits. The interlock circuits must be wired in parallel to a digital I/O board installed in the Motion Control Software. In each status message send to the host, the Motion Real-time Computer reports the status of all interlocks. When a user interlock open circuit is detected, the motion system will respond with a *Forced Settle Abort* as specified in section 3.6.3 and 3.7.

2.8 Emergency Stop Interlock

The motion system has support for one emergency stop interlock circuit, which is wired to a digital I/O board installed in the Motion Real-time Computer and to the Power Distribution Panel. When the emergency interlock circuit is opened, power is removed from all amplifiers leading to activation of the mechanical brakes.

The customer can use the emergency interlock circuit to implement emergency stop buttons on TBD locations. FCS delivers emergency stop interlocks including wiring on the following locations:

1. At the motion control cabinet
2. In the simulator room (location TBD)

2.9 Access Ramp (Optional)

Optionally, FCS Control Systems can design and manufacture an access bridge to the simulator. Standard linear electric actuators can be used or pneumatic actuators. The control of the ramp is a standard software (and electronics) feature.

2.9.1 Ramp Control (Optional)

The access ramp is controlled automatically by the Motion Real-time Computer in response to the Motion Command Word by the host. The ramp movement is monitored by means of two ramp-up switches (one redundant) and one ramp-down switch. For a detailed description of the automatic ramp control, please refer to section 3.6.2 and 3.6.3.

2.10 Smoke and Heat Detection System

Smoke and heat detection sensors are a standard part of the Motion Control Cabinet.

3. E-CUE 636-3500 MOTION SYSTEM SPECIFICATION

This section describes the system specification of the E-Cue 636-3500 motion system. All interfaces are specified in the ICD document.

3.1 Payload

The E-Cue 636-3500 motion system is designed for a payload of 3500 kg. The maximum payload capability, however, depends also on the location of the center of gravity with respect to the Moving Platform Centroid (MPC).

3.2 Platform Dimensions and Interfaces

The platform dimensions and interfaces are specified in the ICD document.

3.3 Performance

3.3.1 Excursions, Velocities and Accelerations

This section specifies the excursion, velocity and acceleration performance of the E-Cue 636-3500 motion system. The specification is given for the Moving Platform Centroid (MPC).

The Moving Platform Centroid is defined as the geometric center of the triangular plane that fits through the actuator joints of the moving frame.

For the E-Cue 636-3500 motion system, the preliminary performance specifications in terms of excursions, velocities and accelerations are listed in the following table. The payload data and location of the center of gravity is determined on the basis of data to be received from AMST. A specification of the mass and inertia breakdown is given in the ICD document.

Table 3-1 Specifications for the E-Cue 636-3500 motion system

DOF	Excursion Limits		Velocity	Acceleration
	Single DOF	Maximum*		
• Surge	• -0.66 / +0.80 m	• ±0.85 m	• ±0.95 m/s	• ±7 m/s²
• Sway	• ±0.65m	• ±0 96 m	• ±0.95 m/s	• ±7 m/s²
• Heave	• -0.55 / +0.64 m	• -0 55 / +0 64 m	• ±0.78 m/s	• ±7 m/s²
• Roll	• ±23°	• ±29°	• ±32 °/s	• >150 °/s²
• Pitch	• ±23°	• -29°/+33°	• ±30°/s	• >150 °/s²
• Yaw	• ±26°	• ±29°	• ±36 °/s	• >200 °/s²

* Envelope fully used with level-3 software only

The above-described operational envelopes are met with the following payload data (see table 3-2).

Table 3-2 Payload data of the E-Cue 636-3500 motion system

• Gross Moving Load (GML)	• 3500 kg
• Payload	• 3000 kg
• GML moment of Inertia about X-axis	• 8000 kg m^2
• GML moment of Inertia about Y-axis	• 8000 kg m^2
• GML moment of Inertia about Z-axis	• 8000 kg m^2
• GML CoG above moving platform centroid	• 1 0 m

3.3.2 Frequency Response

An electro-mechanical actuator includes only steel parts in the load path resulting in a very high stiffness and high natural frequency. Additionally, a controlled servomotor has an extremely good frequency response. Consequently, the frequency response of the whole actuator is very good. In the operating range up to 5-10 Hz there is no noticeable phase lag or amplitude attenuation.

3.3.3 Latency

The motion system software and electronics are designed such that latency is kept to a minimum. As a result, the motion system response will always be faster than the response of the visual system.

An estimate of the worst-case latency is given in the table 3-3. The estimate includes the host to Motion Real-time Computer interface but does not include latency in the host computer.

Table 3-3 Estimate of worst-case latency

Item	Delay
• Host to Motion Real-time Computer Interface (assuming 60 Hz communication rate)	• 15 ms
• Motion Drive Software	• 25 ms
• Actuators	• <10 ms
• Total Worst Case Latency	• <50 0 ms

3.3.4 Acceleration Noise

The peak value of the acceleration in the driven axis does not exceed 0.4 m/sec^2 for a sinusoidal input signal of 10 % maximum velocity at 0.5 Hz

3.3.5 Parasitic Accelerations

Due to the very high mechanical and controlled stiffness of the electro-mechanical actuators the surge - pitch cross coupling and roll - sway cross coupling are decreased to negligible proportions.

3.4 Environment

3.4.1 Audible Noise

The audible noise of the motion system at 1-meter distance during a heave motion at 10% of maximum velocity at 0.5 Hz is 60 dBA.

3.4.2 Power Consumption

The average power consumption of the motion system is 6 kW (peak 18 kW). This figure is low because of the regenerative nature of an electric system. Energy that is required during acceleration, is regenerated during deceleration, and stored in capacitors to be used for the next period of acceleration. The power consumption is determined only by friction and heat losses in the transmission, the motor and the power electronics.

The system can be operated on 3-phase power 380-480 V, 50-60 Hz or any other standardized voltage.

3.4.3 Electro Magnetic Compatibility

The E-Cue 636-3500 motion system has been designed and manufactured in accordance with the European Standards:

- EN 60204 part 1: Safety of machinery - Electrical equipment of machines
- EN 50081 parts 1 and 2: Electromagnetic compatibility. Generic emission standards
- EN 50082 parts 1 and 2: Electromagnetic compatibility. Generic immunity standards

3.5 Motion Cueing

3.5.1 Acceleration Cue Acceptance

The motion software can accept simultaneous acceleration cues in all degrees of freedom and generate motion cues accordingly. The washout filters ensure that the system smoothly returns to the platform neutral position below the perception threshold of the pilot and enable the system to accept new acceleration cues continuously. Moreover, both the rotational motion filters, as the washout filters are adaptive on the basis of platform position and velocity such that the system can handle both small and subtle acceleration cue inputs as well as large and dynamic acceleration cues.

3.5.2 Special Effects

In the context of motion cueing, special effects are those vehicle motions that are not supported by the dynamic simulation model of the vehicle and therefore have to be separately modelled. Mostly, motion cues related to special effects correspond to a discrete event, or have a frequency content that exceeds the bandwidth or fidelity of the dynamic simulation model.

The standard Motion Software does not incorporate a special (buffet) effects generation feature. Instead, the Motion Software vehicle model interface is extended with three input variables, which represent the buffet accelerations of the motion base in surge, sway and heave. Within the Motion Software, these buffet accelerations are high pass filtered and limited (to prevent actuator over travel) and than added to the basic acceleration cues of the main motion drive algorithms and directly converted to changes in motion leg accelerations, velocities and positions. For any buffet acceleration input for roll, pitch and yaw, use can be made of the standard inputs for roll-, pitch- and yaw acceleration.

3.5.3 Motion Cue Correlation and Harmonisation

The motion drive software takes its driving parameters directly from the equations of motion of the simulated vehicle thus ensuring correlation of the motion cues given to the pilot.

The latency of the motion system is minimised to guarantee that the motion system response is always faster than the visual system. Synchronisation of motion cues and Instrumental- and Visual motion cues is possible by adjusting a Delay Tuning Parameter in the motion software.

3.6 Motion System States

The behavior of the system is driven by the state machine implemented in the Motion Control Software for normal operation and under failure conditions, and by the state machine implemented in the MAE I/F units.

3.6.1 Operational States of the Motion Actuator Electronics Interface (MAE I/F units)

A Motion Actuator Electronics unit (MAE) has three states as depicted in figure 3-1. A description of the states and their preconditions are listed below:

- MAE *Off / Abort* state.
  In this state actuator amplifiers are disabled and the mechanical brake is activated. Normally, the *Off / Abort* state is active when the motion system is in the *Off* state. The *Off / Abort* state is also activated when the Motion Real-time Computer has detected a Fail condition. Note that in case of a power failure, the MAE unit is effectively also in the *Off/Abort* state.
- MAE *Active* state.
  This state is active for all normal operational states of the Motion Control Software. More specifically, when the hardware is in the *Active* state, the Motion Control Software can be in any of the states listed in section 3.6.2 except in the *Off* and *End-of-Training* states. When *Active*, the amplifiers are enabled and the brake units are disabled. The *Active* state is only maintained if all of the following preconditions are fulfilled:
  - The *Motion Computer OK* signal is valid, this means that the Motion Control Software is running,
  - The *Actuator Control Loop OK* signal is valid for the actuator. This means that its servo-loop within the Motion Real-time Computer is running normally.
  - The amplifier-enable signal is valid meaning the consistency check between the redundant actuator sensors is positive and the difference between the measured and commanded actuator position and velocity is within predetermined tolerances.
- MAE *Auto Retract* state.
  The *Auto Retract* state is engaged when the *Motion Computer OK* signal is not valid and when the key-switch on the Motion Control Panel is in Auto Retract position. In this state the actuator amplifiers are enabled and the actuator is retracted in response to a constant input voltage to the amplifier. When the settle switched are reached, the *Off / Abort* state is activated.

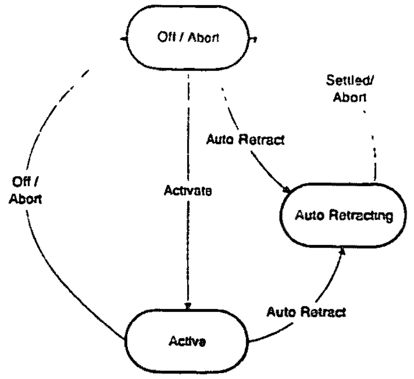


Figure 3-1 States of the Motion Actuator Electronics

3.6.2 States of the Motion Real-time Computer for Normal Operation

Figure 3-2 shows the state diagram of the motion system for Normal operation. This state diagram is build up by so-called *Host Operational States* and *Internal Operational States*. The Host Operational States, shown with a thick outline, represent system target states as commanded by the host computer. The Internal Operational States represent intermediate states and can be regarded as traditional state transients. All shown state transients, depicted as arrows in the state diagram, are instantaneous. As a result, the motion software is always in a defined configurable state, never in a state transient.

Each state transient is triggered by an Event. The name of the Event is specified in the arrow. An event can be generated by a specific host command or by an internal signal (hardware signals, status words of actuator controllers etc). For each host command received, the Motion software sends a status message to the host computer. The host can make use of this message for synchronization.

A description of each state is given below:

- **End of TrainingHold**
  When the motion base is *End of TrainingHold*, the actuator encoder calibration data is lost and therefore the actuator positions are in principle undetermined. In normal operational conditions, however, the motion base is down with all its actuators fully retracted, and resting in the buffers. The ramp is down. The motion system is in settled position and the state of all MAE units is *Locked*. In the EndOfTrainingHold state, the motion system will not respond to any Motion Command Word received from the host because *Motion Consent* is not given. Raising the *Motion Consent* event causes a state transition to the *EndOfTraining* state.
- **End of Training**
  As in the *EndOfTraingHold* state, in the *EndOfTraining* state the actuator encoder calibration data is lost and therefore the actuator positions are in principle undetermined. In normal operational conditions, however, the motion base is down with all its actuators fully retracted, and resting in the buffers. The ramp is down. The motion system is in settled position and the state of all MAE units is *Locked*. The Event *Ramp Up* is generated when the host commands *Disengage*, *Ready For Training* or *Engage* is received.

  When the motion system is not settled, the MAE units of the actuators that are not settled are in *Off/Abort* state. The ramp is up.

- **RaisingRamp (Optional)**
  When all settle switches of the actuators indicate that all actuators are fully retracted, the ramp is being moved up in preparation of engagement of the motion system. The state of all MAE units is *Locked*. The *RampRaised* event is generated when the *Ramp up* switch is detected. Depending on the host command the execution will continue in the *Preparing* state or *LoweringRamp* state.
- **Disengaged (Off)**
  In normal operational conditions, the motion system is settled and the state of all MAE units is *Locked*. In the *Disengaged* state, the calibration information for the actuator position sensor (encoders) is maintained. An *Initialize* event is generated when a *Ready For Training* or *Engage* command is received from the host and the Ramp Up switches are activated. A *Ramp Down* event is generated when an *End-of-Training* command is received from the host.

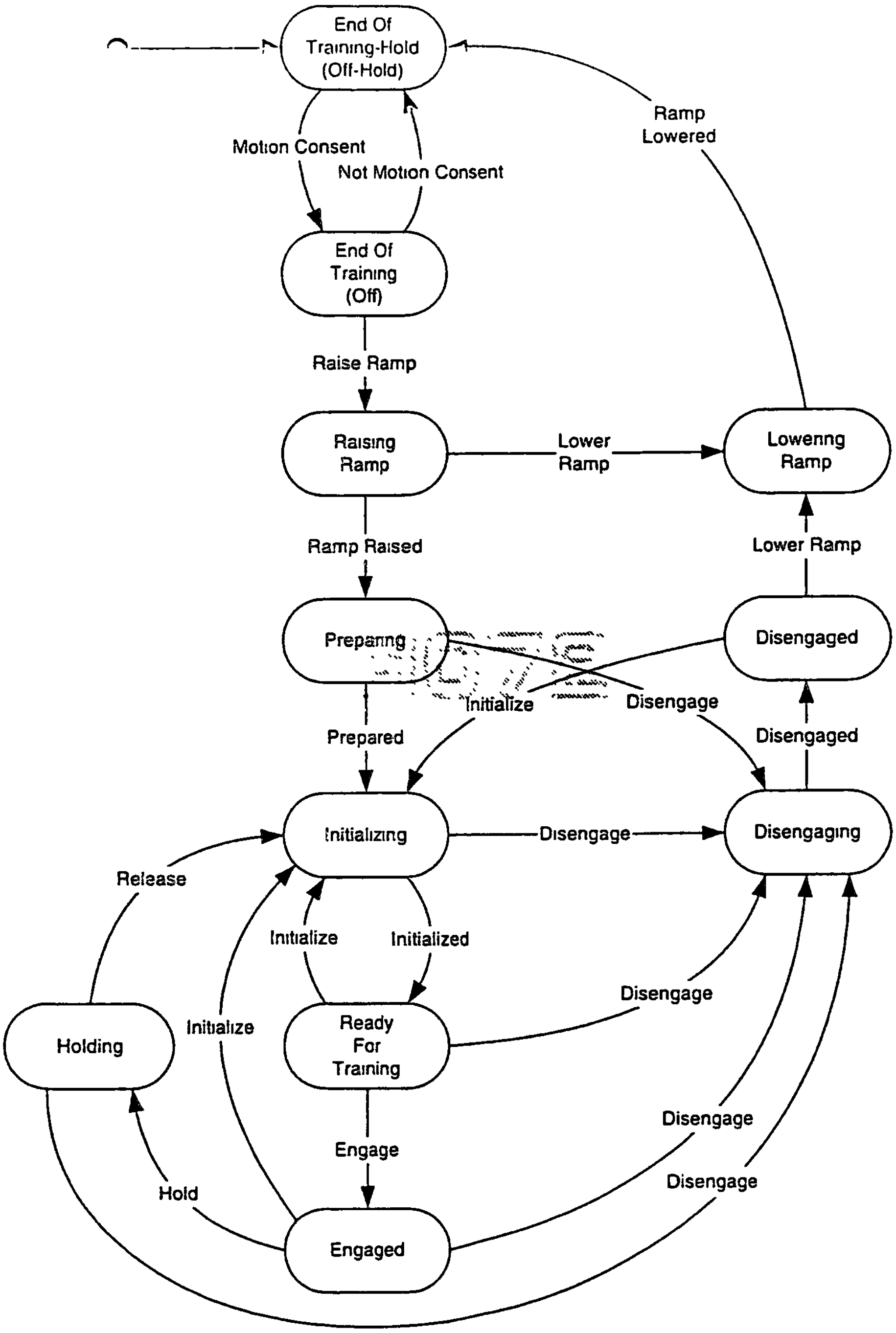


Figure 3-2 The state diagram of the FCS Motion Control Software for normal operation

- **Preparing (internal state)**
  The state of all MAE units is *Active* and the Motion Control Software is waiting until all the actuator controllers have calibrated their encoder position sensors. This state is only executed from the *EndOfTraining* state where calibration information of the actuators is not available. An *Initialize* event is generated when all actuators are calibrated and the host command is *Ready For Training* or *Engage*.
- **Initializing (internal state)**
  The Motion Drive Algorithm is executed to line-up the motion filters using the vehicle dynamic input from the host. A fader circuit is active to provide a smooth transition of the platform set point to an initial position. The platform Kinematics Software calculates the individual control signals for the actuators. The state of all MAE units is *Active*. The *Ready for Training* event is generated when the platform reaches a stationary initial position and a host command *Ready For Training* or *Engage* is received.
- **Ready For Training**
  The motion system is *Ready for Training* when the platform position is initialized and stationary. This means that the platform is stationary in neutral position (all actuators mid stroke) or a non-neutral initial position in case of dynamic initialization. The state of all MAE units is *Active*. An *Initialize* event is generated when a change in the vehicle dynamic input requires an update of the platform initial position. In this case, the active *Ready for Training* state autonomously falls back into the *Initializing* state. An *Engage* event is generated when the host command *Engage* is received.
- **Engaged**
  The motion platform responds dynamically to the vehicle dynamic input from the host. The Motion Drive Algorithm computes the platform target position, velocity and acceleration and the Platform Kinematics Software calculates the individual position, velocity and acceleration signal for each actuator. The state of all MAE units is *Active*. A *Hold* event is generated when a host *Hold* command is received.
- **Holding**
  In the *Hold* state, the vehicle dynamic input to the Motion Drive Algorithm is frozen. The Motion Drive Algorithm remains active but any changes of the host vehicle dynamic input are ignored. The Platform Kinematics Software calculates the individual position, velocity and acceleration signal for each actuator. The state of all MAE units is *Active*. A *Release* event is generated when a host *Ready for Training* or *Engage* command is received. In this case, the active state falls back into the *Initializing* state. If the host dynamic vehicle input has not changed during freeze, the *Initializing* state automatically switches to *Ready For Training* and *Engage* state.
- **Disengaging (internal state)**
  A *Disengage* event is generated by all states when a *Disengage* command is received from the host. In the *Disengaging* state, the platform is smoothly controlled to the settled position. Calibration information of each individual motion actuator is not lost. The state of all MAE units is *Active*. The *Off* event is generated when the platform reaches the platform settled position and the settle switches indicate that all actuators are settled.
- **LoweringRamp (Optional)**
  When all settle switches of the actuators indicate that all actuators are fully retracted, the ramp is being moved to level egress / ingress position. The state of all MAE units is *Off/Abort*. The *End-of-Training* event is generated when the *Ramp down* switch is detected.

3.7 Failure Response Summary

This section specifies the behavior of the system to a number of individual failures. All failures can be grouped into a limited number of error conditions resulting into the same system behavior. A specification is given in the following table:

Table 3-4 Specification of failures and system responses

Category	Cause	System Response
Emergency Abort	• Emergency circuit broken • Fire detected • Ramp not up during simulation (optional) • Ramp sensor mismatch (optional) • Ramp manual override selected during simulation (optional) • Ramp up signal lost when motion system is active (optional) • Mains power failure	• The MAE units of all motion actuators are switched to *Off/Abort* state causing all actuator brake units to be activated • Power is removed from the ramp actuator causing the ramp to lock in current position (optional)
Actuator Abort	• Velocity or velocity-error too high • Position error too high • Actuator sensor mismatch • Power failure at actuator level	• Velocity, sensor or position error is detected in motion software for the actuator channel with the MAE failure • The MAE units of the actuators with the Fail condition are switched to *Off/Abort* state causing the brake unit of this actuator to be activated • Power is removed from the ramp actuator causing the ramp to lock in current position (optional) • All normal operational actuators are controlled to the settled position by the Motion Real-time Computer
Enforced Settle	• Motion consent lost (optional) • Open circuit of any of the user interlocks • Host computer communication failure • UPS Alarm (optional)	• System settle under control of the Motion Real-time Computer within TBD seconds • Directly after retraction to platform settle-position, actuators are locked in place by activation of the mechanical brake • After settling, the access ramp is moved to level egress / ingress position (optional)

3.8 Troubleshooting Capability, Modem Support

In case the motion system has developed some kind of problem, the operator can make use of procedures listed in the troubleshooting documentation to track down the cause of the problem. These procedures make use of the following sources of information:

- The message-stream send by the motion software to the host computer.
- The *Motion Explorer* software.
  The *Motion Explorer* software is a very powerful tool in the context of trouble shooting:
  - The *Motion Explorer* can be used to review the state of the motion system and its components, review sensor signals, connect/disconnect subsystems and change system parameters.
  - FCS can give quick trouble shooting support from its Support Centers in the U.S and Amsterdam by logging into the motion system by modem using the *Motion Explorer*.
  - Since the Motion Software supports multiple synchronous sessions of the *Motion Explorer*, it is possible to set up joint trouble-shooting sessions of FCS specialists and local Maintenance personnel.

3.9 Motion Self Test

The motion software performs a confidence test at start-up of the I/O cards installed in the Motion Real-time Computer. The state of the amplifiers, pneumatic subsystem and power supply is checked continuously during system operation.

Furthermore, the software continuously measures the performance of the actuators against a performance specification baseline.

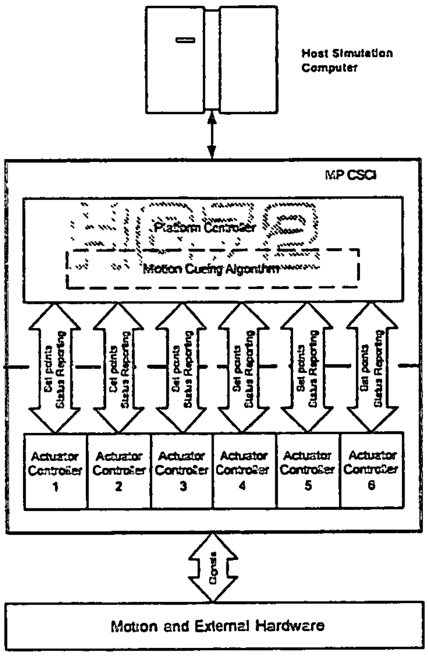
Apart from these test functions, the motion software provides a command interface that allows the motion system to be interrogated by the host computer or by a computer running the FCS Motion Maintenance and Test Software. The customer can also take advantage of this command interface by using it to integrate the motion system into the Simulator Diagnostics- or Operator Interface Software.

3.10 Maintenance

See the MAMS_DSO_ITM (Installation, Troubleshooting, User & Maintenance Manual) document, section 4.

Control Systems

FCS Motion Control Software; FCS Motion Cueing Algorithm; FCSExplorer;



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Date: July 2000

Systems:

All ECue Models

Issue date: March 26, 2001
Issue no: 00-12

Control Systems

Table of Contents

1. Introduction

The ECue family of motion systems provide high fidelity motion cues and safe motion control of the simulator in response to inputs received from a Simulation Host. This task is realized by hardware and software components of the motion system. This document describes the motion control software together with the motion cueing algorithm, which represent the brains of the motion system. The software runs on a VxWorks real-time computer, which is at the center of the motion system architecture.

The functions of the Motion Control Software has control and safety functions. In normal operational conditions, the Motion Control Software has full control over the motion hardware. In non-normal operational conditions, the motion system can be under control by components of the motion electronics/hardware since some detection and handling functions are implemented there. The motion Control Software also has many dedicated failure handling functions such that even in many non-operational conditions still some or all components of the Motion System are still under control by the Motion Control Software. To detect failure conditions, the Motion Control Software continuously monitors actuator performance and response, and external signals such as interlocks etc.

This document describes the functions, features and functionality of the Motion Control Software and its graphical user interface the FCSExplorer.

2. Motion System Software Architecture

Figure 2-1 shows the motion system architecture with the emphasis on the Motion Control Computer and its interfaces.

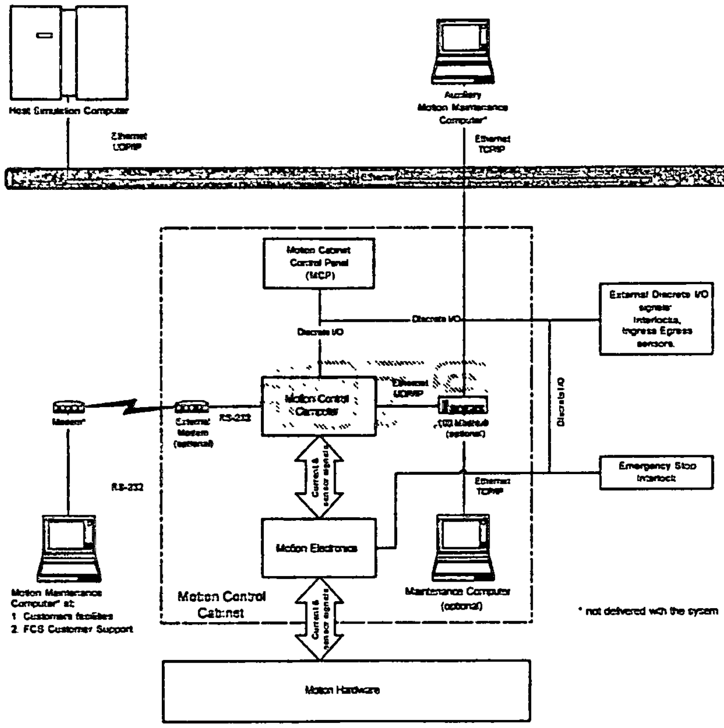

Figure 2-1. The architecture of the ECue product line of motion systems.

The Motion Control Software operates the motion system in response to commands received from the customer Simulation Host via Ethernet. In addition the Motion Control Software implements a number of safety functions at system and actuator level. For this purpose, the Motion Control Computer interfaces directly with external hardware such as interlocks etc.

A Graphical User Interface to the Motion System and the Motion Control Software is offered by the FCS Explorer application. This software application runs on any PC with a Windows OS and can interface with the Motion Control Computer using Ethernet, RS-232 or Modem. Refer to chapter 5 for a description of the functions and features of the FCSExplorer.

3. Motion Control Software

The motion system is controlled by one real-time software application, the FCS Motion Control Software. This software is installed on the Motion Control Computer that is positioned at the heart of the motion system architecture.

This chapter describes the features, functions and functionality to the customer of the Motion Control Software.

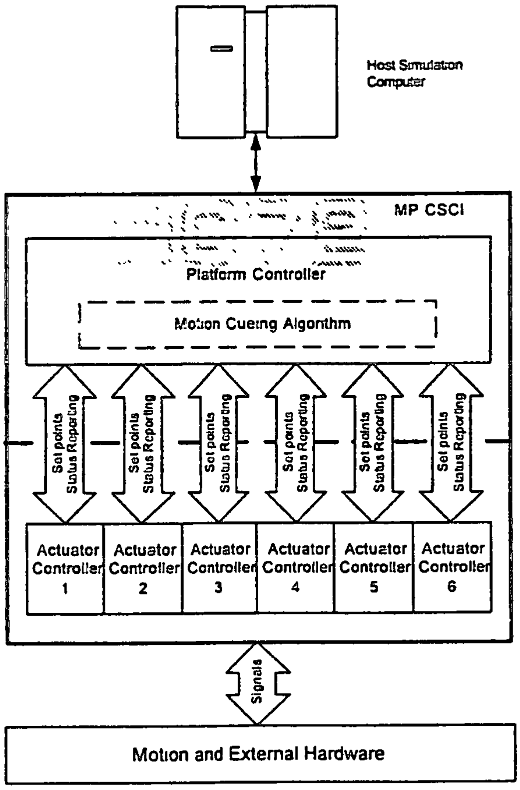

Figure 3-1. The Motion Software is separated into Platform Controller and Actuator Controllers.

As indicated in figure 3-1, the Motion Software is separated into types of controllers the Platform Controller and the Actuator Controller. Section 3.1 and 3.2 describes the functions of the Platform Controller and Actuator Controller. In short, the Platform Controller provides safe controls the motion system at system level whereas the Actuator Controller does the same on Actuator Level. This means that the Actuator Controllers are placed under control of the Platform Controller. In turn the Platform Controller is placed under control of the Host Simulation. This way, the Simulation host has full control over the motion system.

The motion software is available in three levels of fidelity and supports up to 3 modes of operation. Section 3.3 and 3.4 specify these levels and operational modes.

Section 3.5 specifies the interfaces of the Motion Control Software with the Simulation Host.

Section 3.6 introduces two versions of the Motion Control Software, an real-time version running on a VxWorks ROT machine and an emulated version intended running on a Windows OS PC. Customers can make use of the emulated version of development work without the need of the physical motion system hardware.

3.1 The Platform Controller.

The Platform Controller provides safe synchronous control of the motion system in response to inputs received from the Host simulation and external signals such as interlocks etc. In more detail, the functions of the Platform Controller are the following:

- **Control the operational state of the motion system at system level.**
  The Motion Control Software and more specifically the Platform Controller is designed such that the motion system is always under control by a defined operational state. One state defines a part of the operational use and behavior of the motion system. All states together and the state transitions that are defined define the total system behavior including failure detection and handling. There are multiple operational states defined within the Platform Controller of which only one can be active. Of the about 14 operational states, a few examples are given below:

  - End-of-Training: in this state, the motion system is settled and the actuator brakes (electric or mechanical) are activated. The ingress/egress ramp is down
  - Initializing: in this state, the motion system is moving to the initial elevated position as a preparation for training
  - Engaged: the motion system is in this state when actual training is performed. The motion system is responding dynamically to signals from the host. All performance limits are at their maximum values.

- Disengaging. the motion system is moving to settled position due to a host command
- Disengaging: the motion system is moving to settled position due to an internal or environmental error (for example open interlock is detected).

Note that some operational states are so-called failure handling states which are specialized states designed to handle specific failure conditions.

- **Execution of Motion Cueing Model.**
  The Platform Controller contains a so-called motion cueing model, which translates the vehicle accelerations into dynamic set points for the actuators. This is done in such a way that a realistic sensation is obtained in the pilot or driver seat of the real vehicle maneuver. The motion cueing model of FCS is state of the art. A separate discussion of the motion cueing algorithm can be found in chapter 4.

- **Calculation of control signals and dynamic set-points for the Actuator Controller**
  The demanded platform movements as calculated by the motion cueing model are transformed to position velocity and acceleration set points for the Actuator Controllers. In addition, the Platform Controller provides the state commands to the Actuator Controller such that synchronized response is obtained during platform state transitions.

- **Failure detection functions at system level.**
  The Platform Controller interfaces with all major software and hardware components such that can be verified that all motion system components and the simulation environment (through interlocks) are within operational conditions. If an abnormal condition is detected, the appropriate failure handling state is activated which handles the failure condition. Also error message is issued to the Host computer and any connected FCSExplorer session

  Note that the Failure detection functions of the Platform Controller are limited to system level functions. The Actuator Controllers take care of the failure conditions at actuator level. When a failure is detected at actuator level, the Actuator Controller for that actuator handles the failure and notifies the Platform Controller. The Platform Controller than controls the remaining actuators such that a synchronized system response is obtained.

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- **Interfacing with the Host Simulation.**
  The Platform Controller has a bi-directional interface with the Host Simulation. This interface is used for the following purpose:
  - to receive state commands and vehicle dynamic data
  - to send status information to the Host

- **Interface with the FCSExplorer GUI**
  The Platform Controller as a number of integrated functions as to support the FCSExplorer GUI:
  - Provisions for test modes and maintenance activates
  - Support for changing and storing parameter within the tuningsets of the motion cueing model at run-time
  - Monitoring of input and output buffers with the host,
  - Monitoring hardware signals such as interlocks
  - Failure messages
  - etc.

3.2 The Actuator Controller

The Actuator Controller provides safe control of one actuator in response to a state command and dynamic set points received from the Platform Controller and external actuator sensor data. For this purpose the Actuator Controller interfaces with the Platform Controller and with the actuator electronics and sensors.

The functions of the Actuator Controller are as follows:

- **Control the operational state of the motion system at actuator level.**
  The Actuator Controller is designed such that actuator is always under control by a defined operational state. One state defines a part of the operational use and behavior of the actuator. All states together and the state transitions that are defined define the total actuator behavior including failure detection and handling. Like for the Platform Controller there are multiple operational states defined within the Actuator Controller of which only one can be active. Of the about 10 different operational states, a few examples are given below:
  - Off: in this state, the motion amplifier is disabled causing the actuator electric or mechanical brake to be engaged. The actuator is fixed in position or can only moves in a heavily damped manner
  - Preparing: in this state, the Actuator Controller is calibrating the actuator sensors

- Active. the Actuator Controller is in this state when actual training is performed The Actuator is responding dynamically to signals from the Platform Controller All performance limits are at their maximum values.
- Disengaging: the actuator is moving to retracted position.
- Forced Disengaging: the actuator is moving to retracted position due to an non-fatal internal error or an environmental error (for example open interlock is detected by the Platform Controller).

Note that some operational states are so-called failure handling states which are specialized states designed to handle specific failure conditions.

- **Execution of Servo Control Loop.**
The Actuator Controller contains a so-called Servo Control Loop Model. This is a control loop based on feedback and feed forward components which controls the actuator accurately in response to the set-points received from the Platform Controller. This is done in such a way that the velocity and position errors of the actuator are typically within less than 1 mm/s or 1 mm respectively. The Actuator Servo Control Loop model has the following elements:

  - *Performance reference model.* A performance reference model of the actuator filters the set points to the Actuator Servo Control Loop. This ensures that the actuator dynamic performance can follow the dynamic set-points very accurately.
  - *Feedback controller.* The Servo Control Loop has a feedback controller that accepts a position, velocity and acceleration set-point.
  - *Feed forward compensator of actuator internal friction* based on Neural Networks of the actuator internal friction. This results in a virtual elimination of the reversal bump.
  - *Feed forward compensator of the current ripple of the electric motor* based on Neural Networks. This results in an improvement of the smoothness.

- **Interfacing with the actuator electronics.**
The actuator interfaces with the actuator electronics by means of the following signals:

  - two redundant amplifier enable signals
  - the actuator dynamic set-point
  - a heart beat signal indicating the software is running normally. If the heart-beat signal is lost the actuator electronics will activate electric or mechanic brake.
  - various actuator sensor signals.

- **Failure detection and handling at actuator level.**
The Motion Actuator Controller continuously checks whether the actuator is within predetermined operational limits. If these limits are exceeded, the actuator is either electrically or mechanically braked. Some of the failure detection checks are the following:

    - **Actuator dynamic performance checks.**
    The dynamic response of the actuator is checked against a performance baseline. As indicated above, the servo control loop makes use of a performance reference model of the actuator. Even under highly dynamic circumstances, the actuator velocity and position control errors are typically less than 1 mm/s and 1 mm. The failure detection functions can therefore work with very small tolerances for the control errors in position and velocity.
    - **Sensor consistency checks.**
    Consistency checks are between the redundant actuator sensors when applicable. When the sensor error is larger than a predetermined limit, the actuator is mechanically braked and the error is reported to the Motion Platform Controller.
    - **Monitoring of Amplifier status signals.**
    Various amplifier status signals are monitored which report the operational condition of the amplifier.

- **Interfacing with the FCSExplorer GUI**
The Actuator Controller as a number of integrated functions as to support the FCSExplorer GUI
    - Duplication of an servo-loop tuning set, changing tuning parameters and storing tuning sets (password protected)
    - Monitoring of hardware signals.

3.3 Three Operational Modes

Depending on the software level (refer to section 3.4), the motion software offers all or some of the following modes of operation:

- **Simulation mode (Level 2 and 3 only)**
In Simulation mode the vehicle accelerations as send by the Simulation Host are transformed into set-points for the actuators by the motion cueing model. The motion system moves in response to vehicle accelerations received from the Simulation Host.

- **Platform mode (all levels)**
  In platform mode, the motion computer must calculate the actuator set points on the basis of the demanded platform position and angular orientation as send by the Simulation Host.

- **Actuator mode (all levels)**
  In Actuator mode, the Actuator Controller will accept the dynamic set points for the actuators directly from the Simulation Host. The actuators of the motion system move under direct control of the Simulation Host.

The FCS motion software can run these modes either separately or simultaneously. The way this is done is the following:

- Step 1: the FCS motion software computes the simulation mode
- Step 2: the FCS motion software computes the platform degree of freedom mode
- Step 3: the demanded platform movements as computed for both modes are added together.
- Step 4: the resulting demanded platform movements are used for the calculation of the actuator set points.
- Step 5: the host demanded set points are added to the set point following from the simulation and degree of freedom mode.

In order to drive the motion system in these modes, one large host input buffer is defined that contains all the host input signals for these modes.

When a mode is not used, the variables belonging to this modes must be defaulted to zero by the Simulation Host.

3.4 Three levels of fidelity.

The Motion Control Software is available in 3 levels with increasing functionality and fidelity.

3.4.1 Level 1

The level 1 version of the Motion Control Software only supports the platform and actuator modes of operation (refer to section 3.3). The motion cueing model must be integrated within the Simulation Host.

3.4.2 Level 2

The level 2 version of the Motion Control Software support all three modes of operation (refer to section 3.3).

In simulation mode, the Level 2 Motion Control Software only offers a simple Motion Cueing Model. A description of this level 2 is given in section 4.1.

3.4.3 Level 3

The level 3 version of the Motion Control Software support all three modes of operation (refer to section 3.3).

In simulation mode, the Level 3 Motion Control Software only offers the high fidelity Motion Cueing Model. A description of the level 3 model is given in section 4.2.

3.5 Software Interfaces with the Host Simulation

The Platform Controller has a bi-directional interface with the Host Simulation. The Host Simulation sends a so-called Host Input Buffer to the motion system at update frequencies between 10 and 100 Hz. The whole Host Input Buffer is contained in one Ethernet UDP/IP datagram. For each Host Input Buffer received, the Motion Control Software responds by sending a so-called Status Buffer to the Host Simulation. Also the Status Buffer is contained in one Ethernet UDP/IP datagram.

The content of both buffers is given in the next sub-sections. Note that some customization may be necessary.

3.5.1 Host Input Buffer

The parameters in the Host Input Buffer are grouped to variables related to the Simulation-, Platform- and Actuator mode. All variables are listed sequentially in one buffer.

The input variables related to the Simulation Mode of the Motion Control Software are:

- Vehicle Acceleration X
- Vehicle Acceleration Y
- Vehicle Acceleration Z
- Vehicle rotational roll rate

- Vehicle rotational pitch rate
- Vehicle rotational yaw rate
- Vehicle rotational roll acceleration
- Vehicle rotational pitch acceleration
- Vehicle rotational yaw acceleration
- Vehicle buffet acceleration X
- Vehicle buffet acceleration Y
- Vehicle b uffet acceleration Z
- Vehicle driving speed or air speed
- Ground Flight Switch
- (Optional customer dependent variables)

The above buffer assumes that the Host transforms the vehicle acceleration data from the Vehicle CG position to the position of the driver/pilot in the vehicle. If this is not the case, the simulated vehicle CG location must be included in the above input buffer. The position of the driver/pilot in the vehicle frame of reference is part tuningset of the motion cueing model and therefore does not have to part of the host input buffer.

The input variables related to the Platform Mode of the Motion Control Software are:

- Platform demanded displacement position in X, Y and Z
- Platform demanded angle in roll, pitch and yaw
- Platform demanded displacement velocity in X, Y and Z
- Platform demanded roll, pitch and yaw velocity
- Platform demanded displacement acceleration in X, Y and Z direction
- Platform demanded angular acceleration in roll, pitch and yaw

The input variables related to the Actuator Mode of the Motion Control Software are:

- Demanded length for actuator 1, 2, 3, 4, 5 and 6
- Demanded velocity for actuator 1, 2, 3, 4, 5 and 6
- Demanded acceleration for actuator 1, 2, 3, 4, 5 and 6

Note that for the Platform Mode and Actuator Mode variables, not only the demanded displacement- and angular position is required but also complementary displacement- and angular velocity and position signals. This is done as to optimize the platform and actuator dynamic response.

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3.5.2 Status Reporting Buffer

This is standard. In return to each command packet received from the host over Ethernet, the motion system sends the following data to the host:

- The ID of the current operational state of the motion system:
  - EndOfTraining state (settled)
  - ReadyForTraining state (neutral position)
  - Engaged (motion system is engaged in dynamic simulation)
  - Disengaging (the motion system is settling)
  - etc.
- The status of external hardware such as:
  - all safety interlocks
  - power supply data
  - pneumatic subsystem
  - etc.
- The status of all Actuator Controllers
- The current position, velocity and acceleration of the motion platform both for displacements as for the angular orientation.
- For each actuator the current length, velocity and acceleration.

Other reporting variables can be added on customer specification when the data is available within the motion software.

3.6 Supported Operating systems

3.6.1 VxWorks version

The real-time version of the Motion Control Software runs on the VxWorks RTOS (Tornado version 1.1). The VxWorks RTOS requires a Board Support Package (BSP) that ports the VxWorks kernel to a specific hardware platform. The MP software runs using a kernel image derived from the standard Tornado 486 BSP tailored to include support for (Pentium processor) floating point routines, processing of the bootline from a file instead of hard coded information in the BSP, and the inclusion of the FTP and Telnet daemons. The kernel also configures the FEI network driver for the Intel PRO/100 network card.

3.6.1.1 Hardware dependencies

The VxWorks version of the Motion Control Software runs on an Industrial PC with the following specifications:

- Processor: Pentium II or III 300 Mhz or faster
- 16 Mb RAM memory
- Harddisk or IDE compatible solid state disk > 3 Mb
- floppy drive
- Between one and four CIC cards to interface with the actuator electronics (FCS supplied card)
- One or more ISA Digital I/O card to interface with external hardware
- Fast Intel Eternet card

3.6.2 Windows 95/98/NT/2000 version

A windows 95/98/NT/2000 emulated version of the Motion Control Software is available in which all external motion hardware is emulated. The emulated application provides 100% compatibility with the VxWorks version including interfacing with the Simulation Host and FCSExplorer through Ethernet. The customer can use this emulated version for interface development work without the need for the physical motion system.

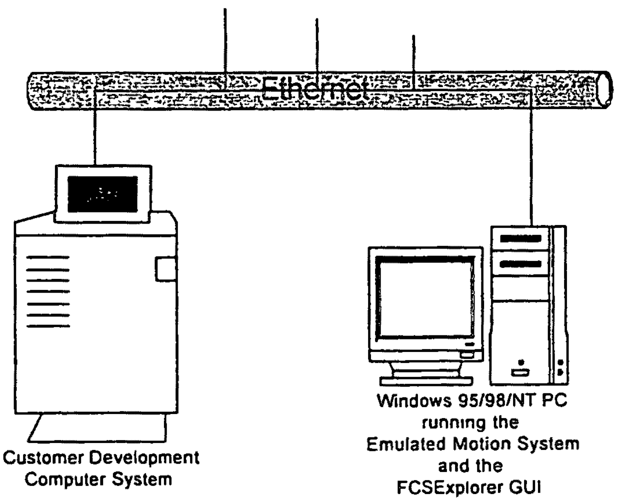

Figure 3-2 Support for customer development work.

3.6.2.1 Hardware dependencies

The Windows version of the Motion Control Software runs on standard a laptop or desktop PC. There are no special requirements on the configuration other than that a Fast Ethernet card must be installed.

4. The Fokker Motion Cueing Model

The Motion Cueing Algorithm is a model within the Platform Controller. During dynamic simulation, the Motion Cueing Algorithm transforms the real vehicle accelerations, provided by the Host computer, into accelerations, velocities and positions of the moving platform (refer to section 3.5.1 for a list of the necessary input parameters). This is done in such a way that the sense of realism in the driver or pilot seat is maximized.

The Motion Cueing model is highly parameterized, which allows tuning of the motion cueing algorithm to the dynamics of the simulated vehicle and to the kinematic design of the motion system.

FCS offers two versions for the Motion Cueing Algorithm. A basic version is delivered with the Level 2 Motion Control Software. The Level 3 Motion Control Software offers the advanced state-of-the-art version of the Motion Cueing Algorithm. This version includes the Advanced Platform Kinematics algorithm which greatly enhances the motion cueing fidelity.

The Level 1 Motion Control Software does not offer a Motion Cueing Model.

4.1 Motion Cueing Model for Level 2 Motion Control Software.

The Level 2 Motion Control Software offers a standard motion cueing model.

The model includes six high pass translational channels for all degrees of freedom and two low pass channels for pitch and roll as to simulate sustained accelerations. All channels include adjustable limiters and gains. The model is fully parameterized including the position of the design eye-point such that the model can be tuned to the dynamics of the simulated vehicle, the kinematic design of the motion system and the design of the cabin.

The main difference of the level 2 and level 3 cueing models is that the level 2 model does not include adaptive elements such as gain scheduling and adaptive washout.

4.2 Motion Cueing Model for Level 3 Motion Control Software

To explain the features of the Level 3 Motion Cueing software, the concept of Kinematic Workspace versus Dynamic workspace must be introduced.

- **Kinematic Workspace.**
  The Kinematic Workspace of a motion system are the combination of theoretical excursions that the motion system offers. Mathematically, the Kinematic Workspace is an odd complex shape in 6 dimensional space. All combinations of excursions that are mapped within the shape are possible for the motion system to produce. And the other way around: all combinations outside of this shape are impossible for the motion system to produce. A reflection of this workspace is the excursion specification sheet of a motion system although this does not show the cross coupling[1] between individual degrees of freedom.

- **Dynamic Workspace.**
  From the viewpoint of a motion systems Kinematic design, the Dynamic Workspace is that part of the Kinematic Workspace that is actually used during dynamic simulation. Viewed from the perspective of simulation, another definition can be given: the Dynamic Workspace defines the collection of real vehicle maneuvers that can be represent in a way judged by a human pilot/driver as realistic to the vehicle.

The reason that a distinction is made between Kinematic and Dynamic workspace is that in standard Motion Cueing Software (such as the level 2 software) a large part of the Kinematic Workspace is inefficiently used or not usable at all. This is due to the mathematical complexity of the kinematics of synergistic 6 DOF motion system (the odd complex shape!). Where the motion systems Kinematic design aims at optimizing the Kinematic Workspace, the Level 3 has a number of features designed at maximizing the Dynamic workspace of the platform. These features increase the perceived size of the motion system in comparison with a situation where standard software is used.

The main features of the Fokker Motion Drive Software are the following:

- **Complementary Low Frequent and High Frequent motion filters.**
  The vehicle longitudinal and lateral accelerations are simulated by longitudinal and lateral platform excursions and low frequent platform pitch and roll rotations. The complementary low and high pass filters make sure that the motion cues that are simulated through platform

[1] Note that synergistic motion systems have strong cross couplings, i.e., when a motion system moves in degree of freedom X, the excursion workspace in the other degrees of freedom is reduced (sometimes strongly!).

translation are not repeated in some frequency area by platform rotations (and visa versa). This increases motion cueing fidelity.

- **Specific Force Error correction.**
When the platform produces high frequency roll and pitch acceleration cues, the resulting platform pitch and roll angles generate false acceleration cues in lateral and longitudinal direction because of the rotation of the gravity vector in the simulator cabin body axis. The Specific Force Error correction reduced this effect by performing platform translation accelerations in opposite direction.

- **Advanced Platform Kinematics Algorithm (APK algorithm).**
The APK algorithm has a mathematical solution of the Kinematic motion envelope in 6 dimensional space. On this basic knowledge the following features are developed:

  - APK: Estimation of remaining excursions.
  For each moment in time, APK estimates accurately the remaining platform excursions in all degrees of freedom. This estimate is used for gain scheduling of the high pass translation channels.

  - APK: Prediction and Inverse Washout.
  For the immediate future, APK estimated the trajectory of the motion system follows through its motion envelope. APK then introduces small parasitic accelerations in longitudinal, lateral and vertical direction that optimize the trajectory of the motion system through its motion envelope. This concept is called Inverse Washout.

  - APK: Simultaneous adaptive washout in surge, sway and heave.
  Combined adaptive washout in Longitudinal, Lateral van Vertical direction simultaneously. Since APK is mathematically defined in 6 dimensional space, washout in Surge, Sway and Heave could be combined into a washout vector. This makes washout more efficient. The washout is intensified if the motion system approaches its Kinematic limits. This adaptive mechanism allows the motion system to be tuned for the majority of maneuvers instead of for a handful of extreme maneuvers that happen only a small percentage of time.

  - APK: Dynamic pre-positioning.
  The favored position of the motion system within its motion envelope can be manipulated allowing external pre-positioning of the motion

system within the motion envelope. This can be used to prepare the motion system for extreme maneuvers.

- APK· Reduction of the sensitivity of the height of the design eye-point. High positions of the design eye-point are with standard software unfavorable because platform rotations, that should take place about the eye-point, then also require large translation excursions. This wastes a large part of the platform Kinematic workspace. With the APK algorithm, low frequent platform rotations to take place about a non-fixed rotation point, which is optimal from a Kinematic viewpoint. Only high frequency components of the platform roll, pitch and yaw excursions take place about the pilot eye-point. This largely reduces the sensitivity of the motion cueing fidelity for the height of the Design Eye-point since the lower frequency components produce the largest platform pitch and roll excursions.

- **Adaptive Gain scheduling**
  The level 3 software offers adaptive gain scheduling based on the momentary remaining platform excursions in Surge, Sway, Heave, Roll, Pitch and Yaw direction.

- **Support for multiple tuning sets**
  The above features and other parts of the software can be tuned to the dynamics of the aircraft by more than 260 categorized tuning parameters which are collected into a named tuning set. The motion cueing model supports of multiple tuning sets that can be selected and deselected by the host at run-time. This may be used to switch between different vehicles, flight conditions and training tasks.

- **Support of multiple Motion Cueing models.**
  The software supports multiple Motion Cueing models, can be selected and deselected by the host at run-time. This may be used to switch between different vehicles, flight conditions and training tasks.

- **Special effects.**
  Special effects can be added to the Level 3 Motion Cueing Algorithm on customer request.

5. The FCSExplorer GUI to the Motion Control Software

The Motion Explorer is a Graphical User Interface (GUI) for the Motion Control Software and Motion System and can be used for the following purposes:

- (customer) development work
- system tests
- maintenance activities
- tuning of motion cueing model and servo control loops
- (remote) troubleshooting activities

The Motion Explorer is a stand-alone Windows 95/98/NT application. Figure 2-1 shows that this user interface is either executed from the Maintenance Computer, which is installed in the Motion Control Cabinet (Optional), or from a customer supplied external/remote PC which is linked to the Motion Computer through a Ethernet, RS-232 or Modem connection. This architecture supports remote diagnostics with multiple Explorer sessions active at the same time which offers the possibility for synchronous local and remote troubleshooting activities.

After start-up, the Explorer must 'Log In' to the FMCS application user one of the communication interfaces. After the connection is established the FMCS Application uploads its list of components to the Motion Explorer. The Explorer is then capable to displays this information in two different views, the 'Schematic View' and the 'Browse View', which can be selected at will by the user.

The 'Schematic View', as depicted in Figure 5-1, shows a block diagram of the components of the Motion System and is especially designed for local maintenance personnel. All of the system components shown have tabulated dialogs that can be activated by simple point-and-click mouse actions. These dialogs give detailed information about the status of the component and present links to underlying components, which have their own dialogs.
For easy traceability in case of system errors, the background color of each component is used to encode the failure state of the component. Green encodes a component within operational limits while flashing red indicates that a failure has occurred. Selecting these objects with the mouse will give information about the state of the selected object including warning and error messages.

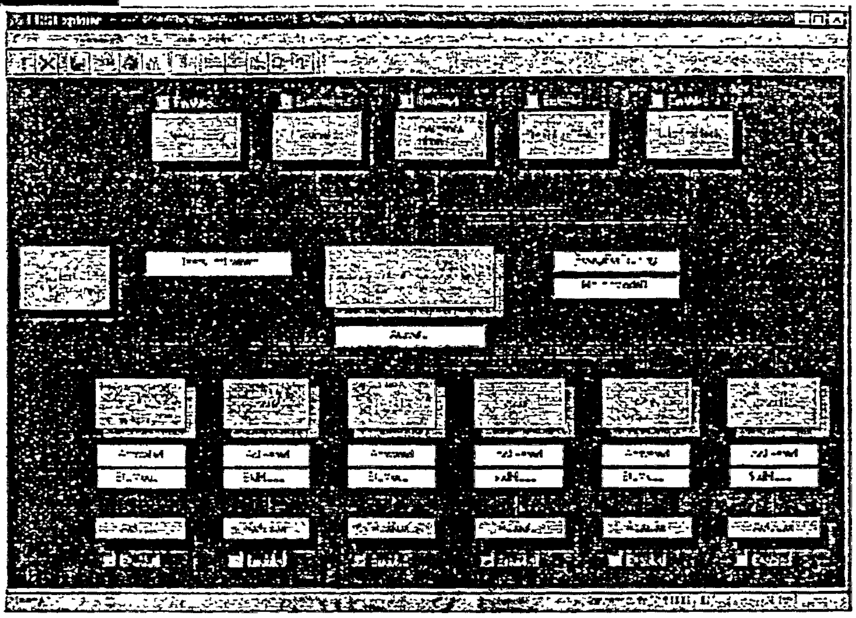
Figure 5-1 The 'Schematic View' of the Motion Explorer.

As an alternative to the 'Schematic View', the Explorer offers an in-depth 'Browse View' as shown in figure 5-2. The visual appearance of the 'Browse View' conforms the Windows 95 file explorer. The left panel contains the browse tree which hierarchically lists all software and hardware components such as:

- actuators,
- controllers,
- models,
- states,
- variables,
- parameters
- signals to- and from the hardware.

The right panel shows the contents of any selected component in the left panel. All of the dialogs offered by the 'Schematic View' are still accessible by clicking on the appropriate components within the browse tree.

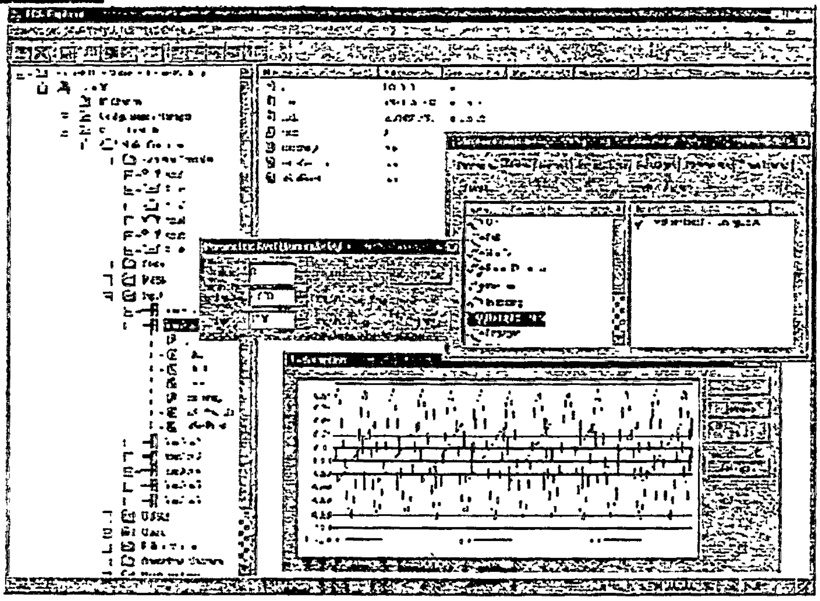

Figure 5-2 The in depth 'Browse-View' of the Motion Explorer.

The 'Browse View' offers a more technical and more detailed view of the motion system and its components. The user can start browsing at the top-application level and browse all the way down to the pin-level of the hardware I/O cards. At any level, variables and signals can be viewed numerically or graphically using a sampling window. Model parameters can be selected and permanently changed which is an essential feature necessary for tuning of the motion cueing model and the servo control loops.

To safeguard the configuration of the simulator when in operation, all parameter changes are protected by means of a password mechanism.

6. Main Features of the FCS motion software

The main features of the motion software offered by FCS are the following:

- Available in 3 levels of fidelity.
- Support for separate or combined operation in Simulation mode, Platform mode and Actuator mode (Level 2 and 3 versions only).
- Availability of Emulated version of the Motion Control Software for PC Windows platforms as to simplify the customer development environment.
- Executes the state-of-the-art the FCS Motion Cueing Model.
- The Advanced Platform Kinematics Algorithm makes the following features available (Level 3 only):
  - Adaptive gain scheduling based on momentary remaining excursions.
  - Inverse Washout based on prediction of future motion.
  - Simultaneous adaptive washout in surge, sway and heave
  - Dynamic pre-positioning
  - Reduction of the sensitivity of the height of the design eye-point.
- Standard support for multiple motion cueing models and tuning sets. Active motion cueing model and tuning set can be selected at runtime by means of a host command.
- The actuators are controlled by a dynamic set points consisting of a complementary position, velocity and acceleration signal which are mathematically directly derived from the vehicle accelerations as received from the Simulation Host
- High Bandwidth control of the actuators due to the use of acceleration, velocity and position feedback control.
- Compensation of actuator friction through Neural Network technology eliminating reversal bump.
- Full safety detection and handling at motion system level and actuator level.

- Bi-directional 100 Mbit Ethernet interface with the host.
- Standard detailed status reporting to the host including failure messages
- Support for automatic control of an ingress/egress bridge is included.
- Emulated Motion Control Software package available for Windows/PC platform as to support customer development activities.
- Powerful Graphical User Interface offered by the FCSExplorer software.
  - Integrated support for development, test, maintenance and troubleshooting activities.
  - Support for remote trouble-shooting through modem connection.
  - Parameter values are protected by means of a User/Password mechanism.

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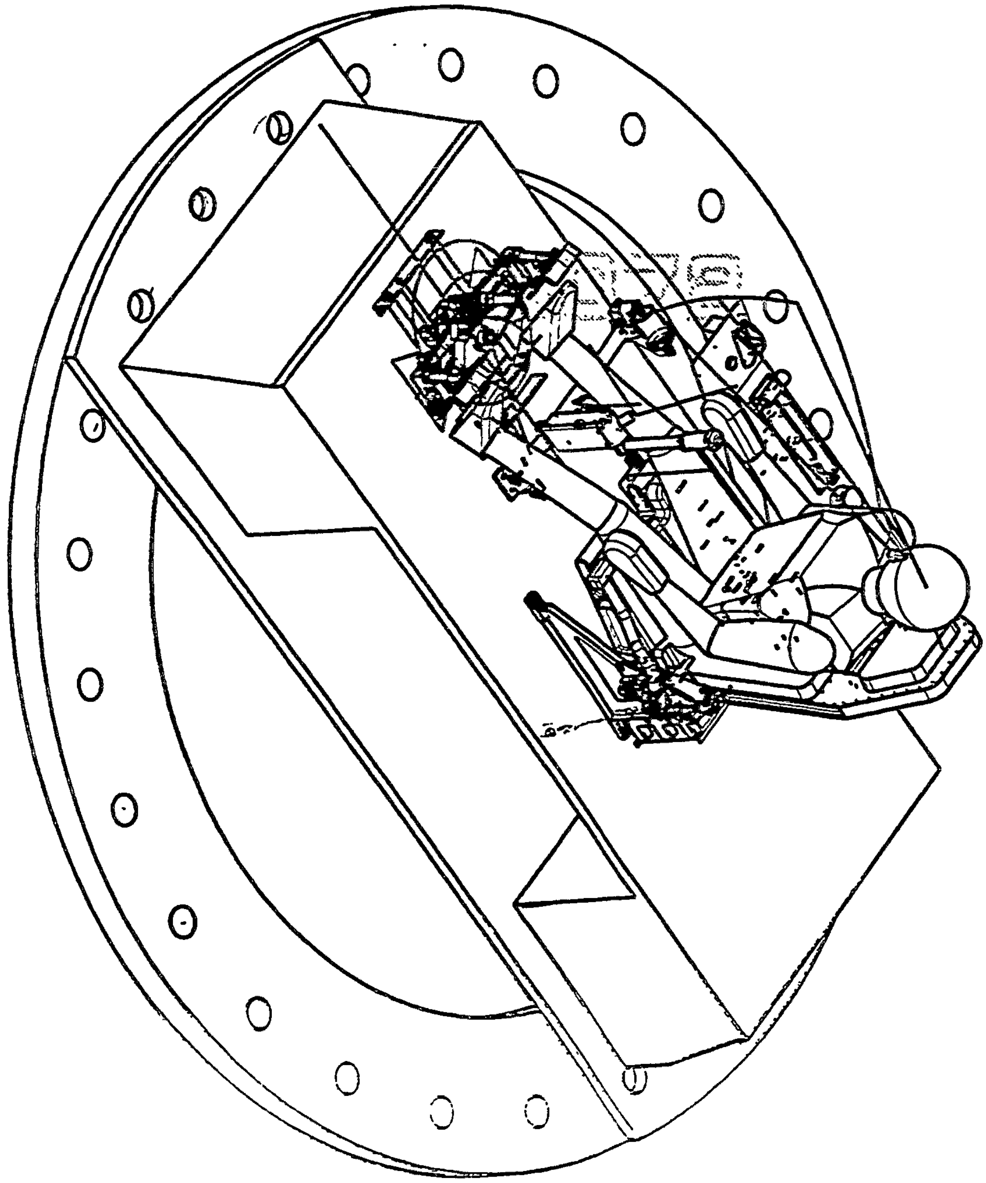

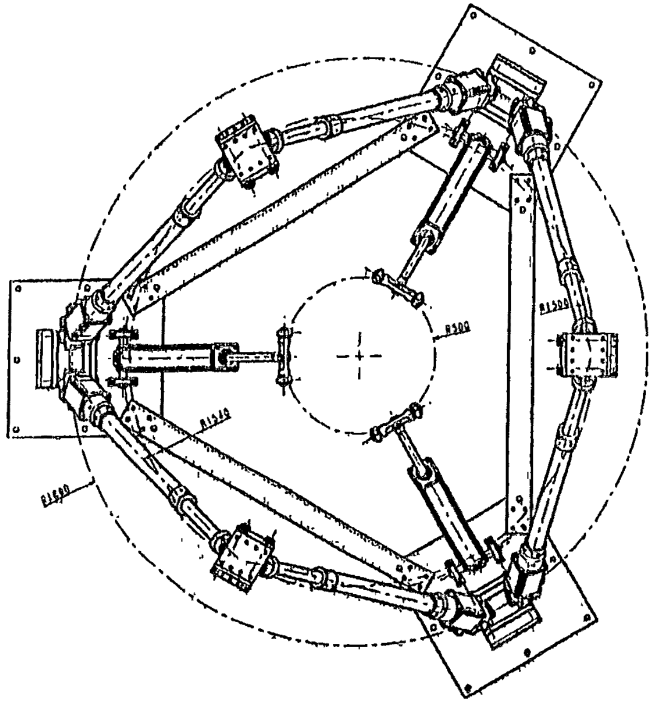

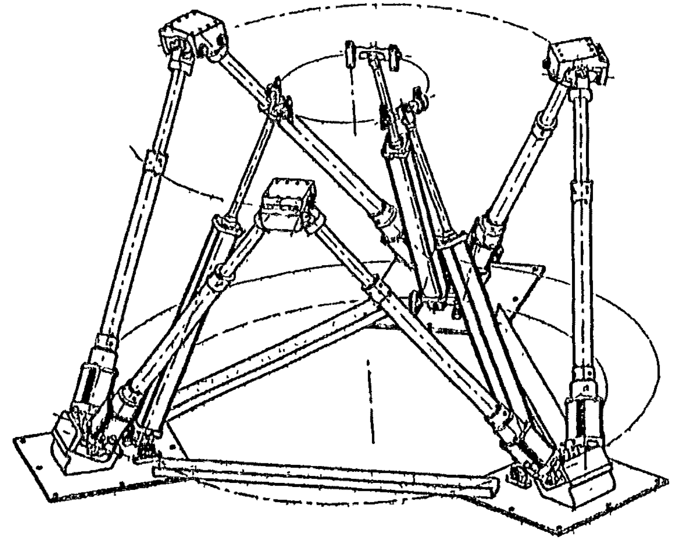

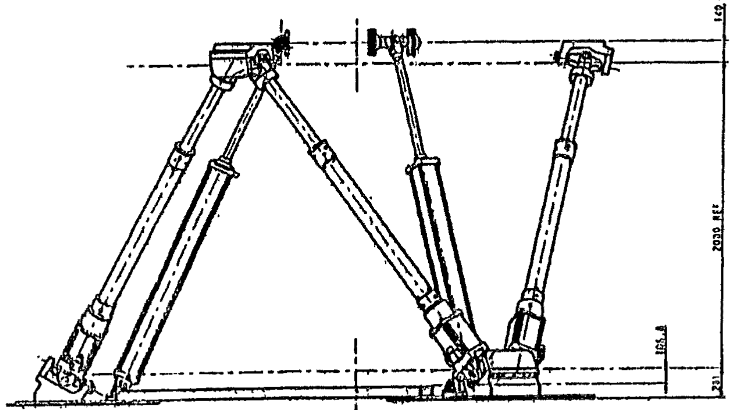

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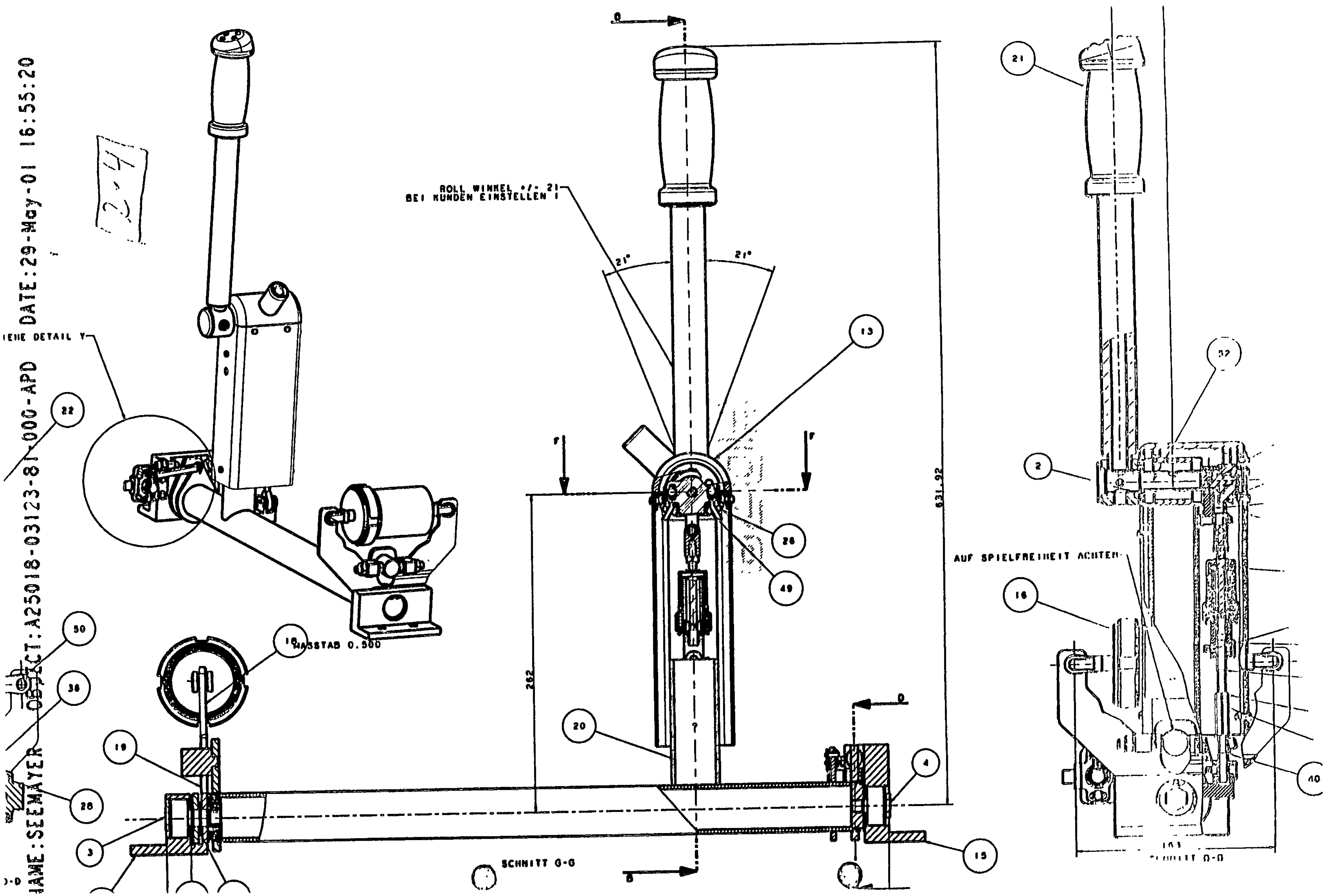

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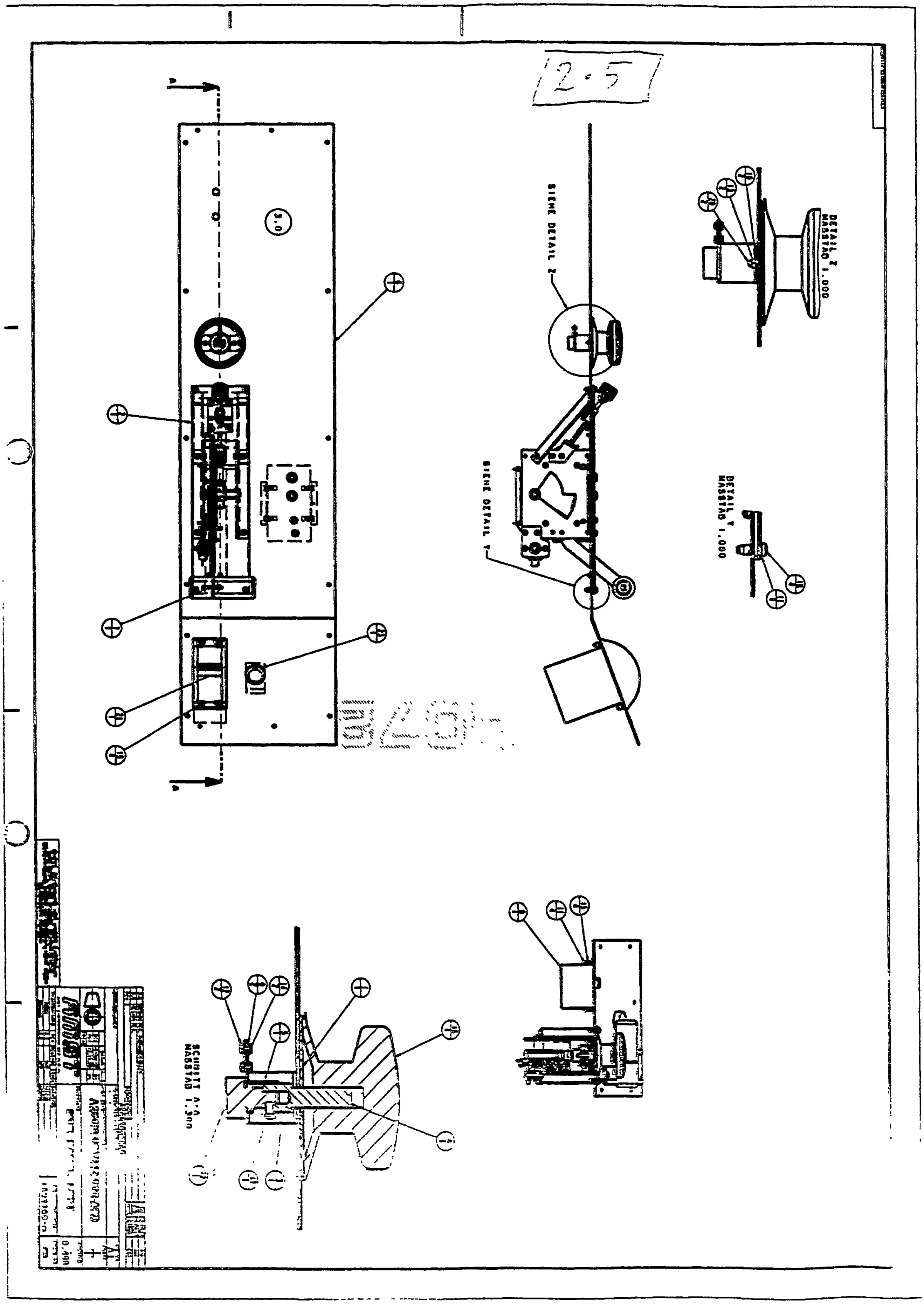

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