Shuttle Orbiter

Remote Manipulator System

Mechanical Systems

Exploratory Development

0 Shuttle Orbiter was designed with a capability to transport large Payloads

0 In general the concept was to bring varied payloads to various orbital altitudes and inclinations

0 Initial Orbiter configuration had a large payload bay with a significant payload capability – 65,000lbs, 15ft diameter, 60ft long.

0 Initial design did not define a concept for handling payloads

0 NASA resources were used to assure Shuttle Transportation System's flight worthiness as prime objective

0 Manipulator Concepts were initiated in the early 1970's – competed for resources with other programs:

- Skylab
- Apollo Soyez Test Project
- Prime objective of Shuttle Transportation System

Exploratory Development – Concept Definition

0 NASA Centers explored many concepts – all had shortcomings

0 Most payload handling systems were designed to perform either deployment or retrieval tasks. None were proficient at both tasks.

0 Manipulators were contenders once requirements became more refined.

0 JSC - Spacecraft Design Division began to assign resources to understand the functions, design and operations of manipulators

0 Initial studies included use of available Atomic Energy Commission manipulators that were designed for remote handling of radio active items

0 Analyses indicated that exploratory hardware development was necessary

0 Objectives were to determine the mix of handling and design requirements

Concept Development

0 Initial test with master slave systems indicated that several design requirements were not compatible with ergonomics or available resources of the Orbiter Flight Deck
    - Large sweep volume was required
    - Ratcheting of master to change movement ratio

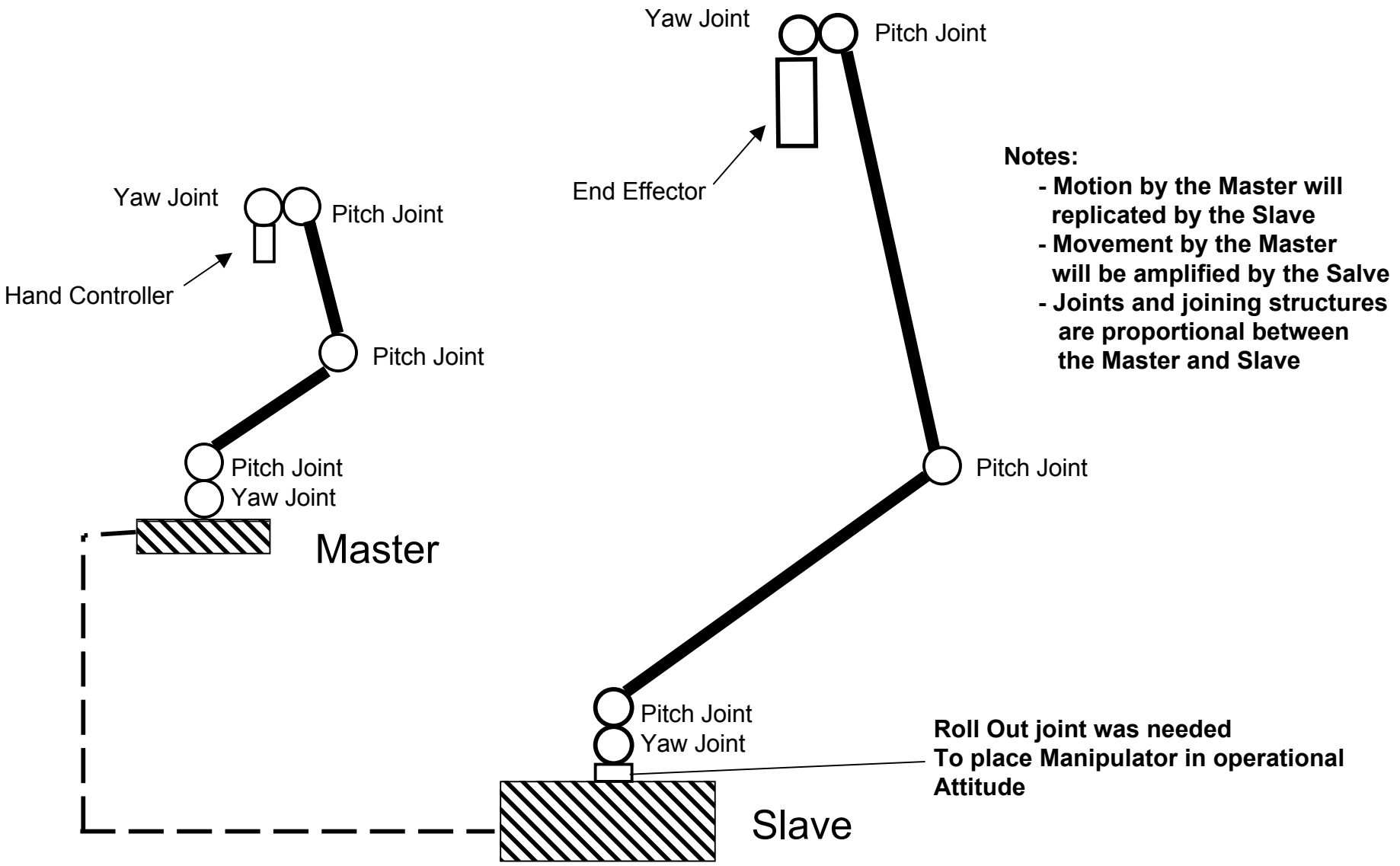
0 The tactile feedback was very desirable for dexterous operations

0 Available master-slave units were of small size; though dexterous, amplification to a large cargo handing system was marginal

0 During several tests, operators arm became tired

0 Master-slave concept was maintained for future testing – other control schemes analysis were initiated

Master – Slave Concept



Determination of Concept Requirements

0 Initial operations indicated that a larger system was needed to determine needed requirements

0 An industrial Manipulator was purchased to continue concept development
- A G.E. hydraulic manipulator was located
- It was formerly used by Pittsburgh Plate Glass Co.
  - 25 feet long used for moving plate glass
  - Master-Slave control system
  - Vacuum end effector

0 Several concept elements to be analyzed
- Master-Slave/alternate concept
- Feedback vs fixed hand controller
- Viewing – line sight/TV
- End effector configuration
- Power source
- Size, joint speed, tip speed
- Payload/cargo handling
- Satellite Capture and Retrieval

Small Facility – Building 13 High Bay

0 The larger manipulator required a much larger floor space to accommodate the initial development and anticipated growth-manipulator approx 30ft

0 Analysis indicated that an air bearing floor was needed

0 The Initial floor was about 25 ft by 30 ft in size; the floor was sufficiently smooth to accommodate:

- Heavy weight payloads- air bearings
- Stationary payloads
- Free flying satellites- air bearings

0 Initial findings determined several requirements

- Master-slave system was used but not optimum
- Feedback was not a facilitator
- Line of sight and TV would be required
- No suitable end effector configuration was defined
- End effector tip speed was defined
- Moving satellites could be captured and retrieved
- Analyses defined that an orbital hydraulic system was not optimum

Larger Facility – Building 9A

0 Larger facilities were required to develop and confirm requirements

0 As requirement developed, full scale Orbiter mockups were needed to prove scale integrity

0 In addition to the full scale Orbiter Trainers/Mockups, an entire building was fabricated to confirm manipulator proof of concept

0 A new smoother floor was fabricated – approximately 60ft x 40ft

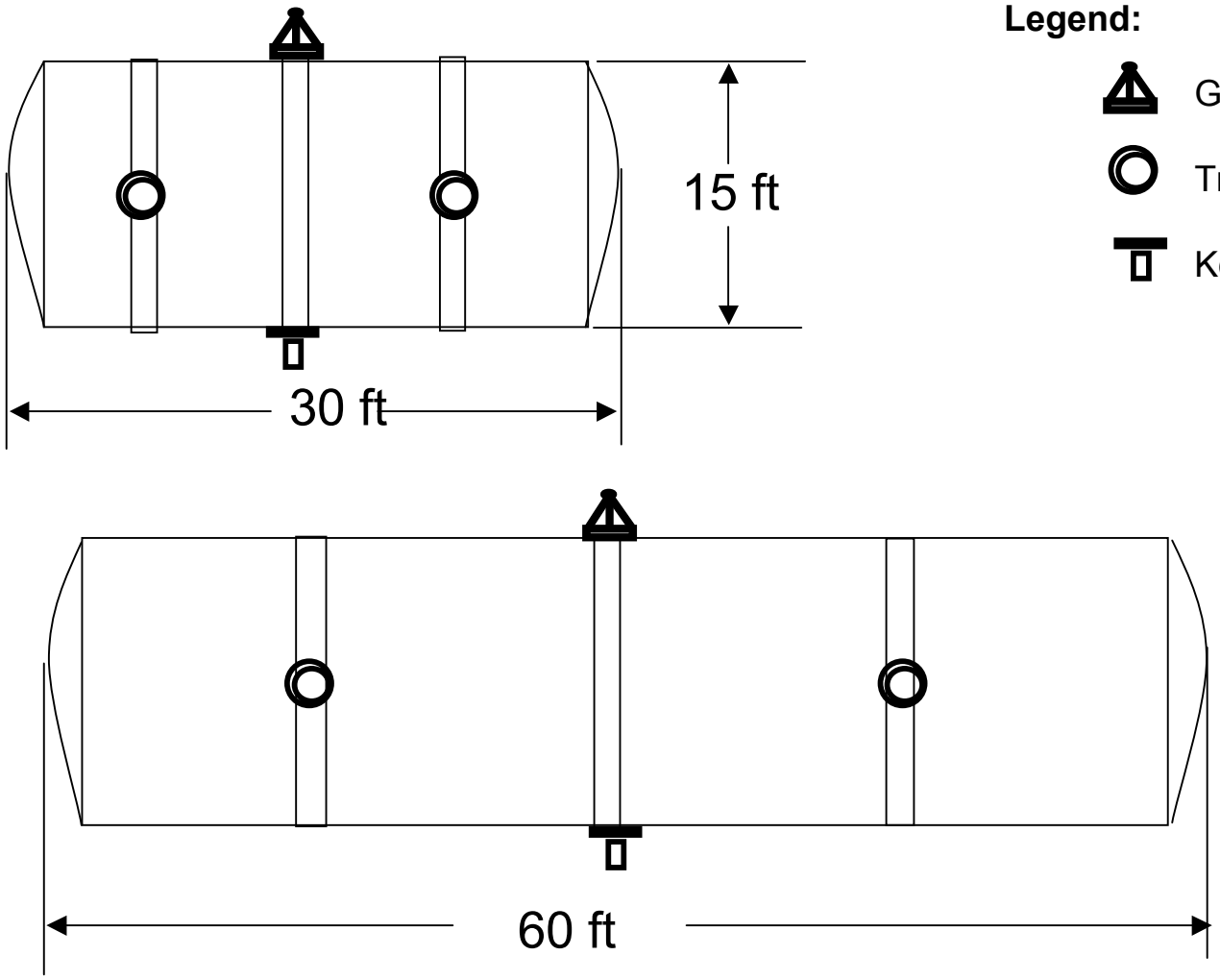
0 Manipulator sized increased to simulate concept for Orbiter and installed in a full scale mockup – 50ft length with hydraulic to simulate electrical system

0 Large scale payloads were also needed

0 A complete retention system was also devised to hold the payloads

0 Analysis and design began to develop a fixed hand controller concept

Payload Simulations - Inflatables



Legend:

- Grapple Fixture
- Trunion
- Keel Fitting

Note:

- **Inflatables were helium filled**
- **Low weight/good inertia**
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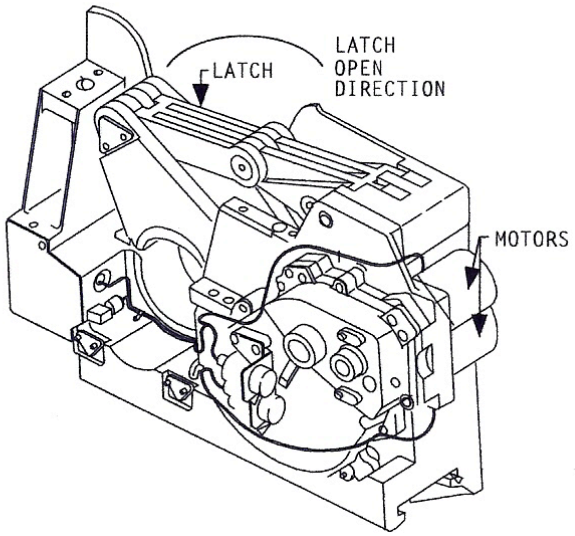
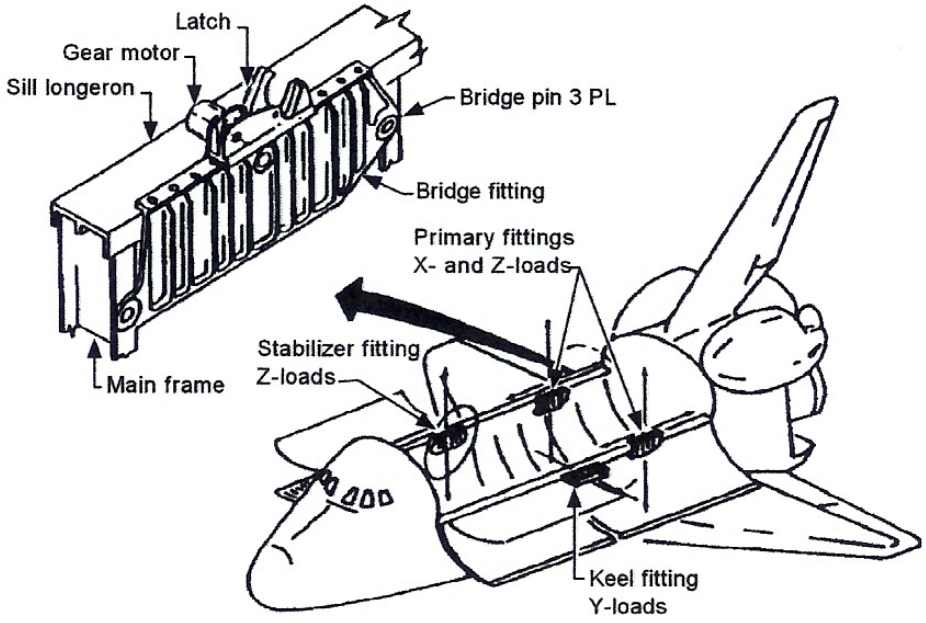
Orbiter – Trunion Latches

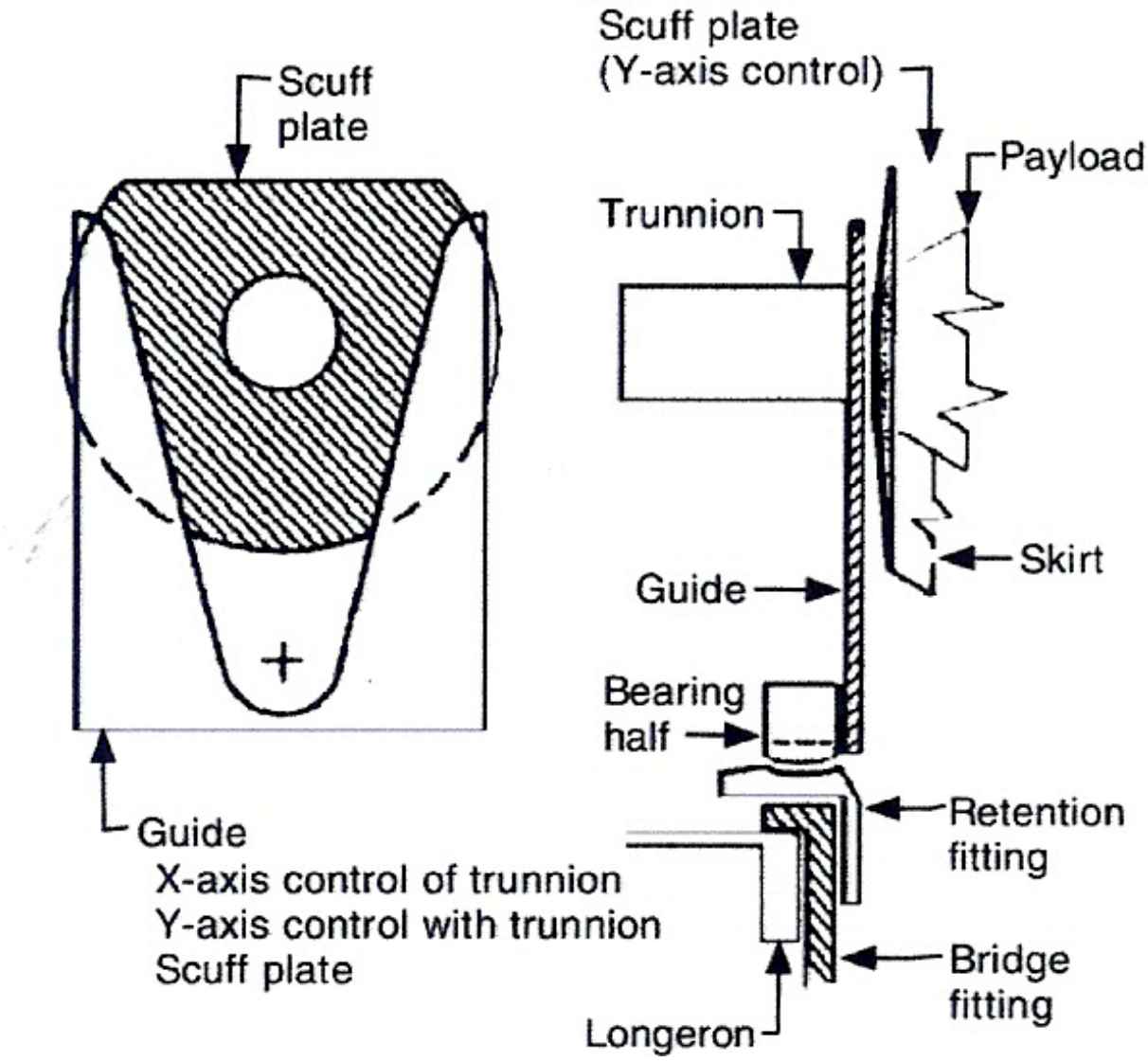


Trunion Latch – Four Places

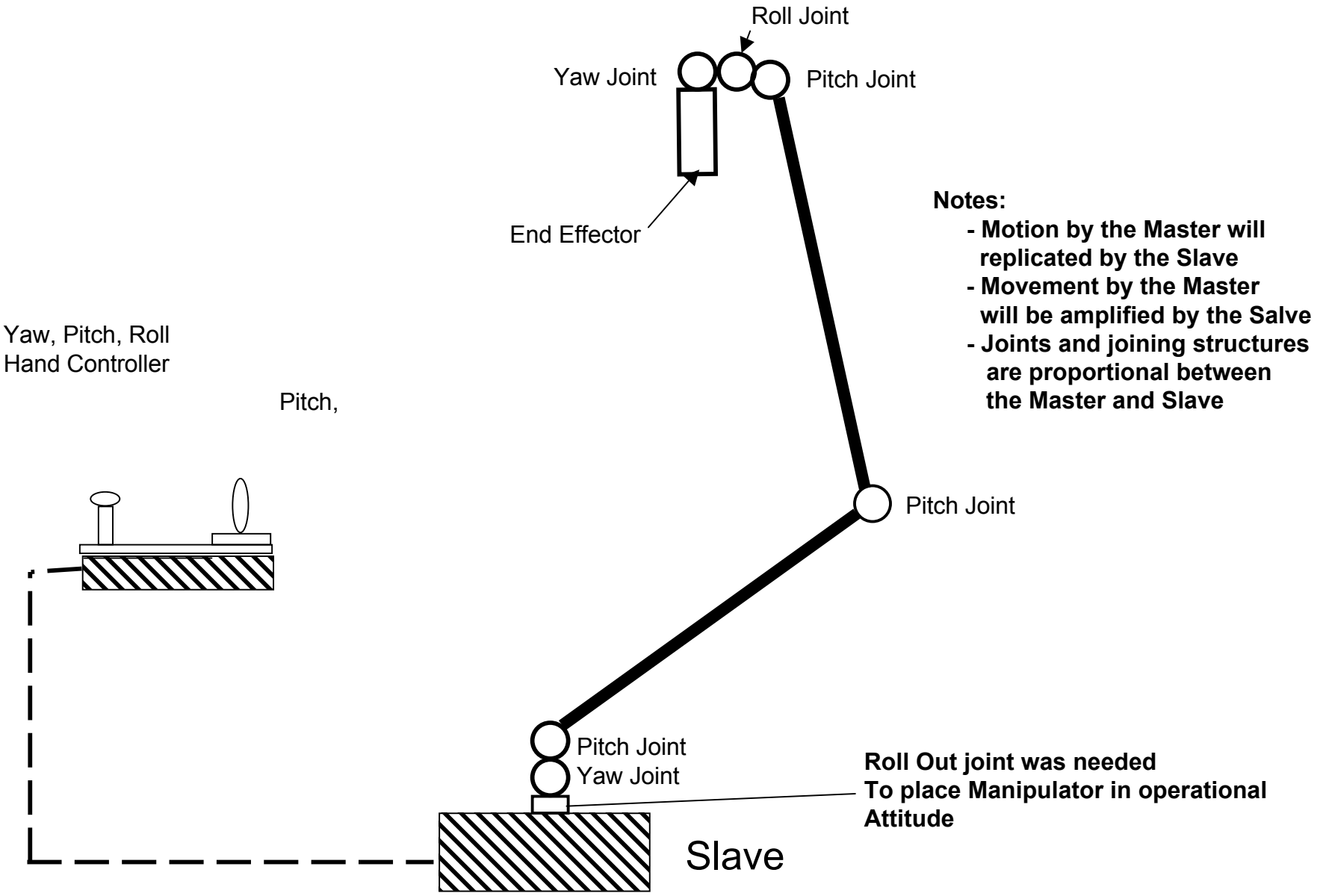


Active Payload Retention System
(V-Guides Not Shown)

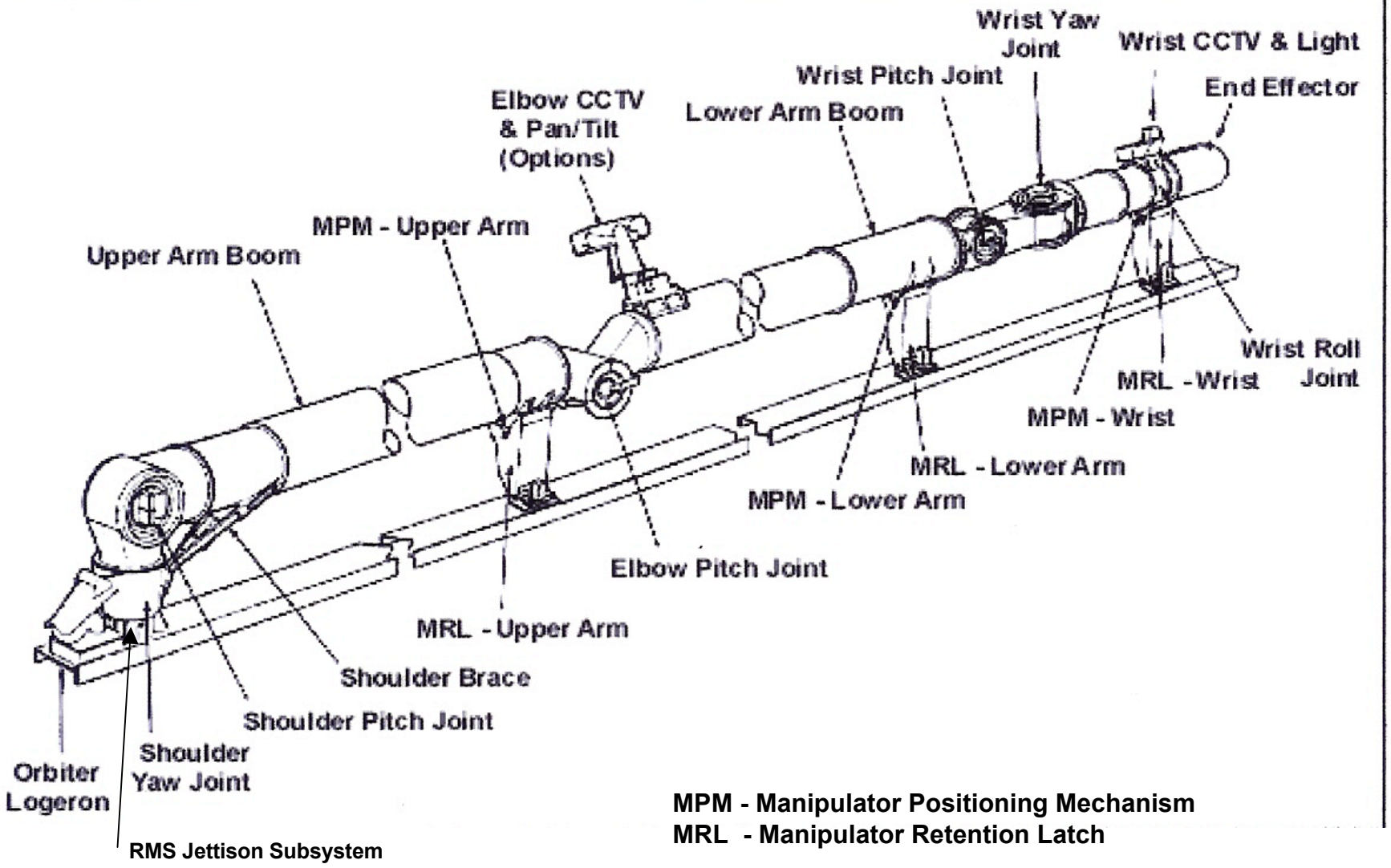
Orbiter Payload - V Guide & Scuff Plate



Hand Controllers - Manipulator



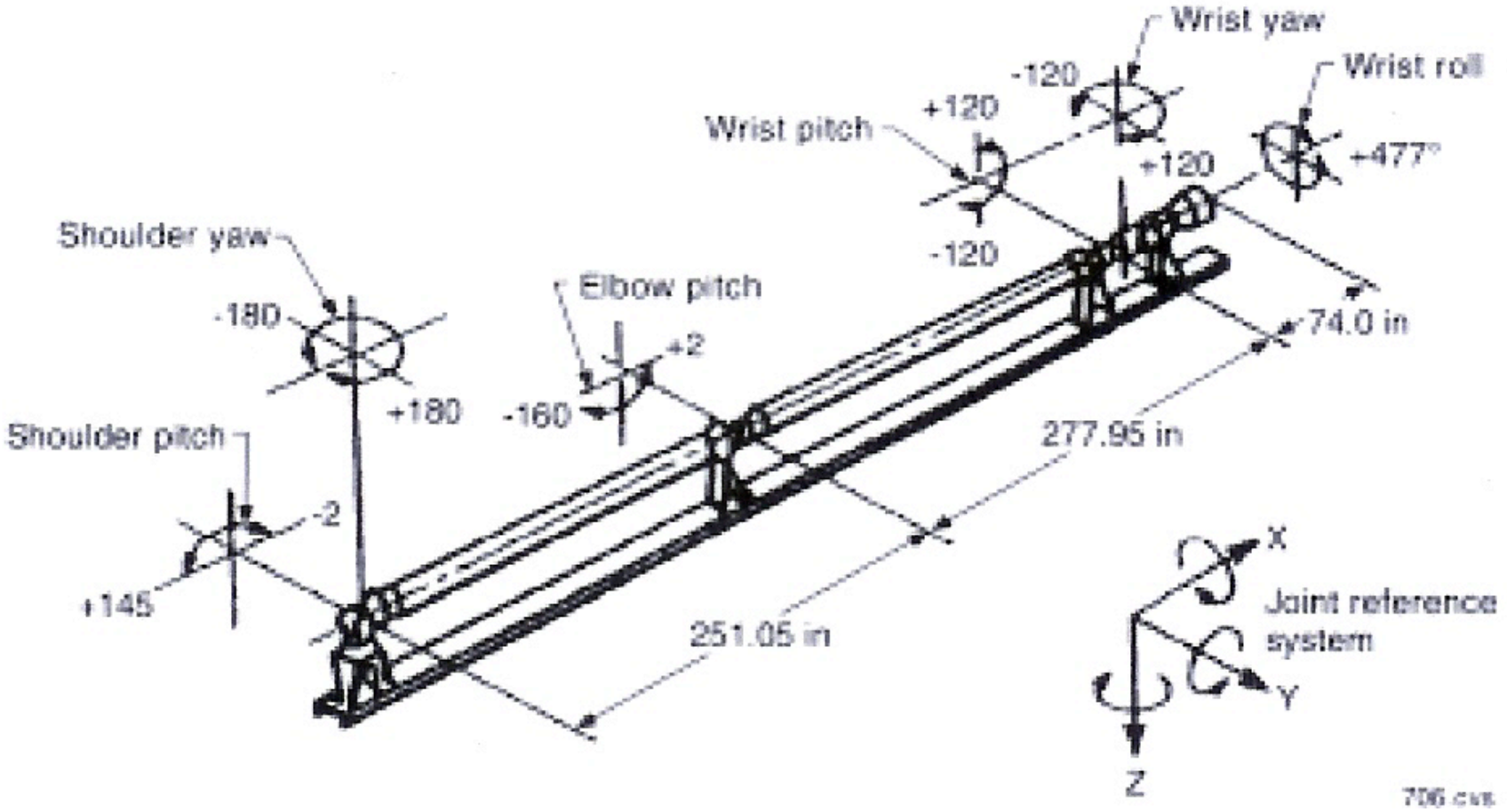
Orbiter Remote Manipulator



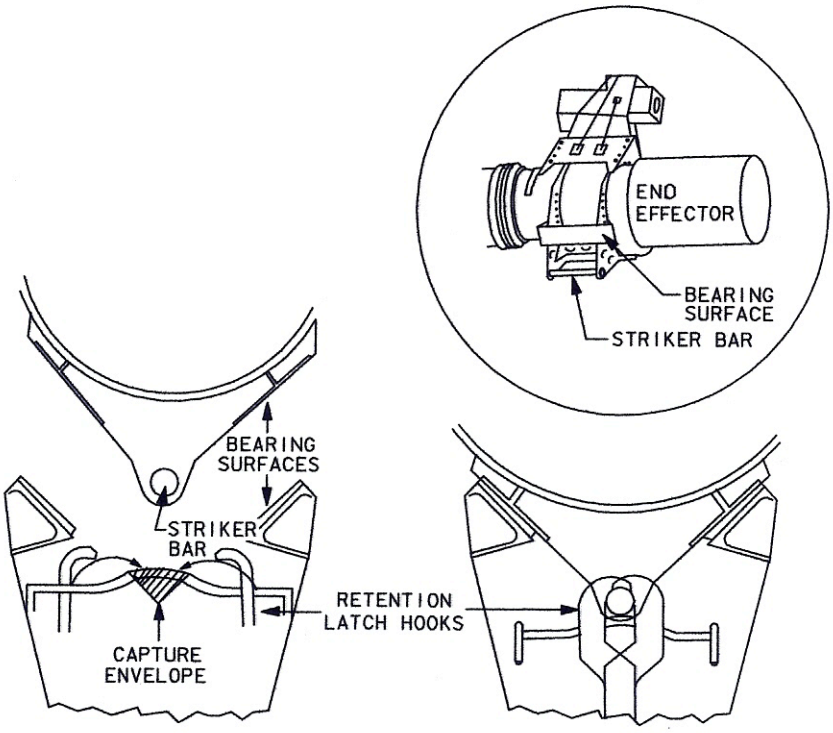
MPM - Manipulator Positioning Mechanism
MRL - Manipulator Retention Latch

Note:
RMS jettison interface is at base of MPM on longeron

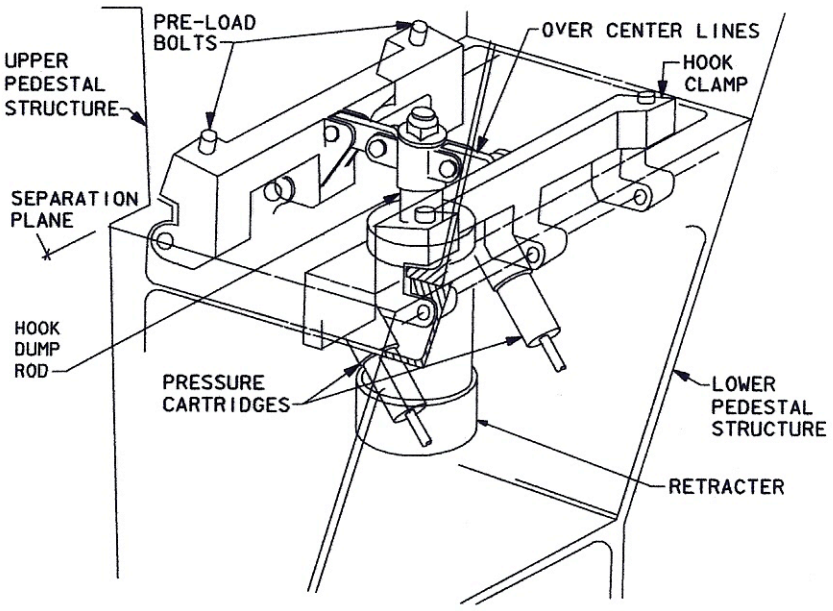
Orbiter RMS – Dimensions & Joint Limits



Manipulator System Retention System

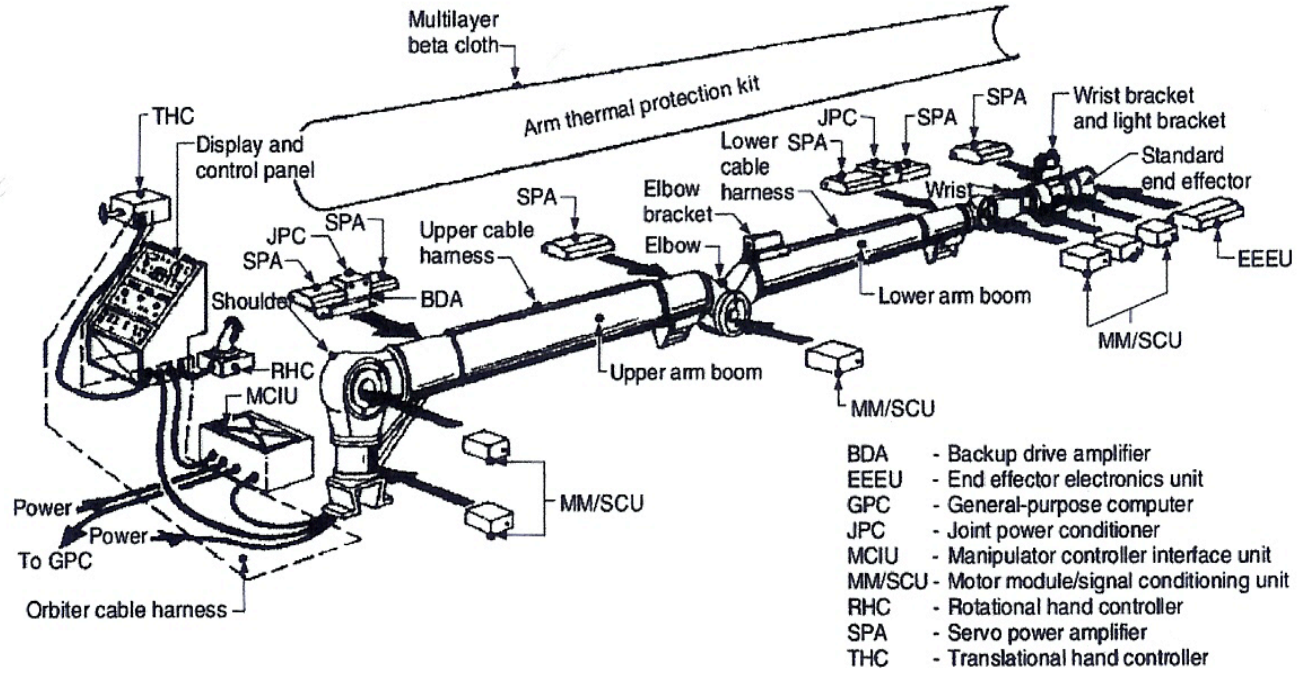


RMS Retention Mechanism

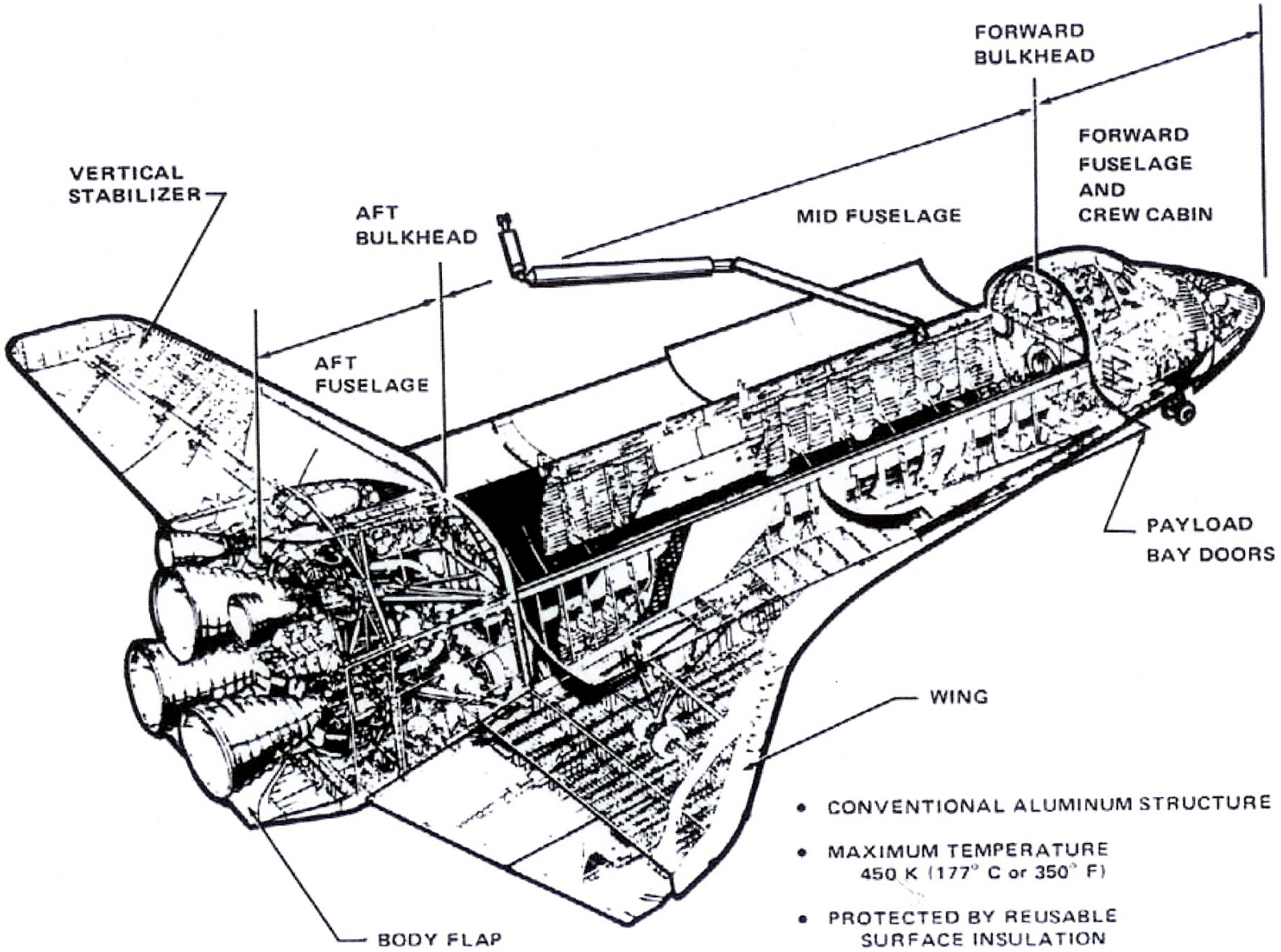


Jettison System

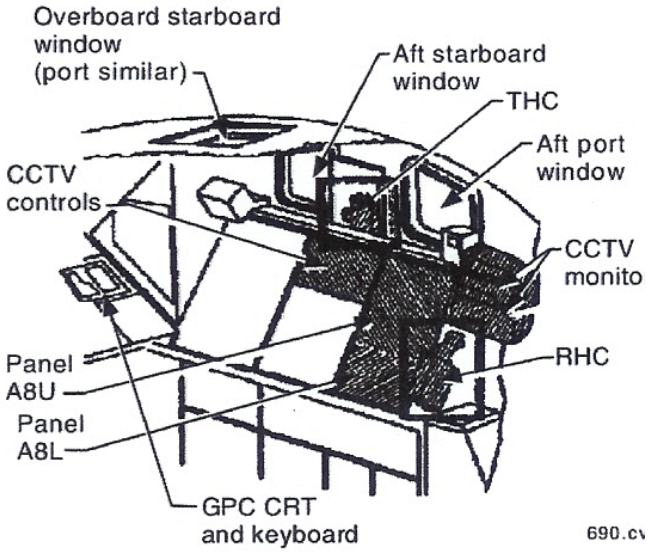
Orbiter Remote Manipulator System Avionics

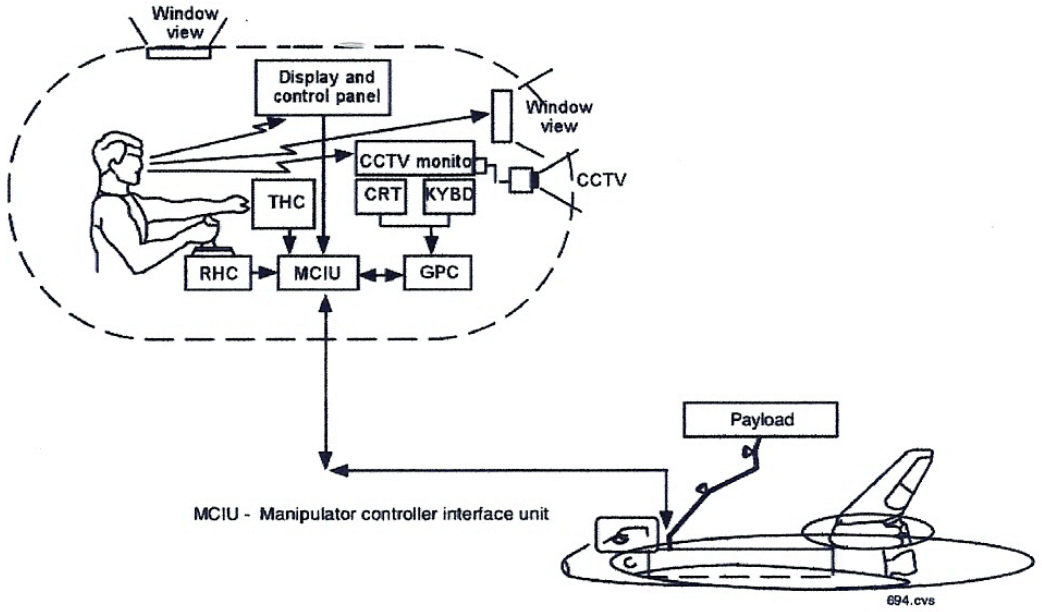


Orbiter Payload Bay

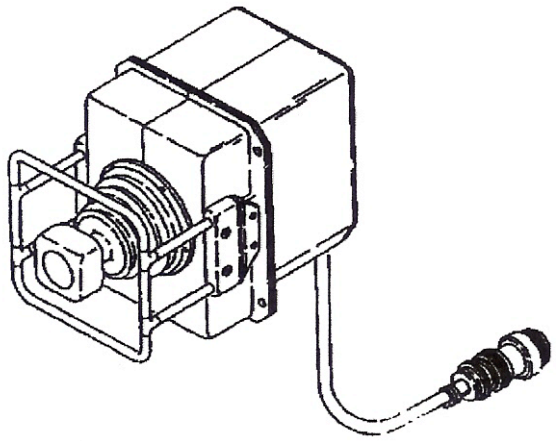


Orbiter Flight Deck Work Station

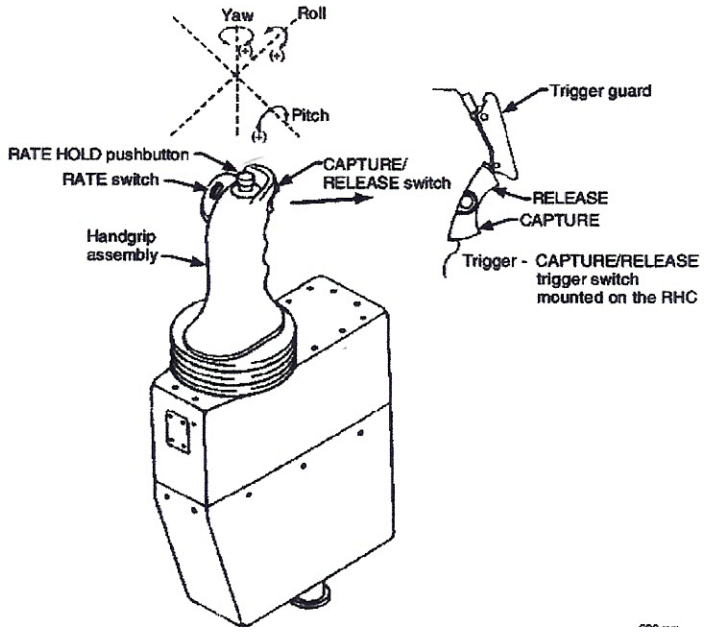




Orbiter Hand Controllers

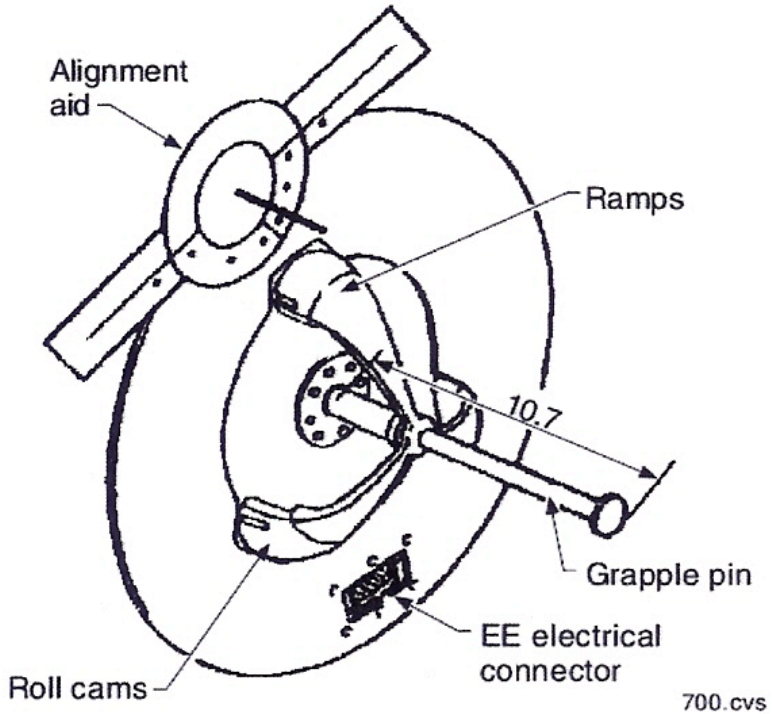


Translation Hand Controller (THC)

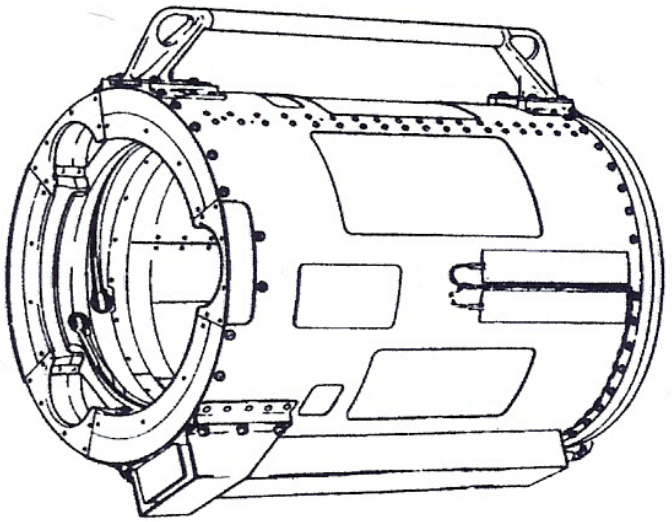


Rotational Hand Controller (RHC)

Payload Grapple Fixture – End Effector



Grapple Fixture



End Effector

Backup – Failure Modes

0 Backup Mode

- Joint or electrical failure was most likely necessity for a backup mode
- **Single** Joint mode
  - As implied, commands a single joint
  - This mode is computer supported
- **Direct** joint mode
  - Commands single joint
  - Commands transmitted by hard wire

0 Jettison

- Failure that would prohibit RMS operation
- Would jeopardize safety
- Non propulsive jettison is performed
- Expedited Jettison is also available

Concluding Remarks – Remote Manipulator System

0 Though initial requirements were not well defined, the use of development concepts and hardware did enhance a workable system

0 Use of available technology and equipment expedited the derivation of the the flight design

0 Integration of the Crewman into the system did require adjustments in the the control system

0 Initial inflatable testing was crucial in determining feasibility and viability of the design

0 International cooperation was not a hindrance in Remote Manipulator development

0 The initial design though upgraded with improvements is still flying