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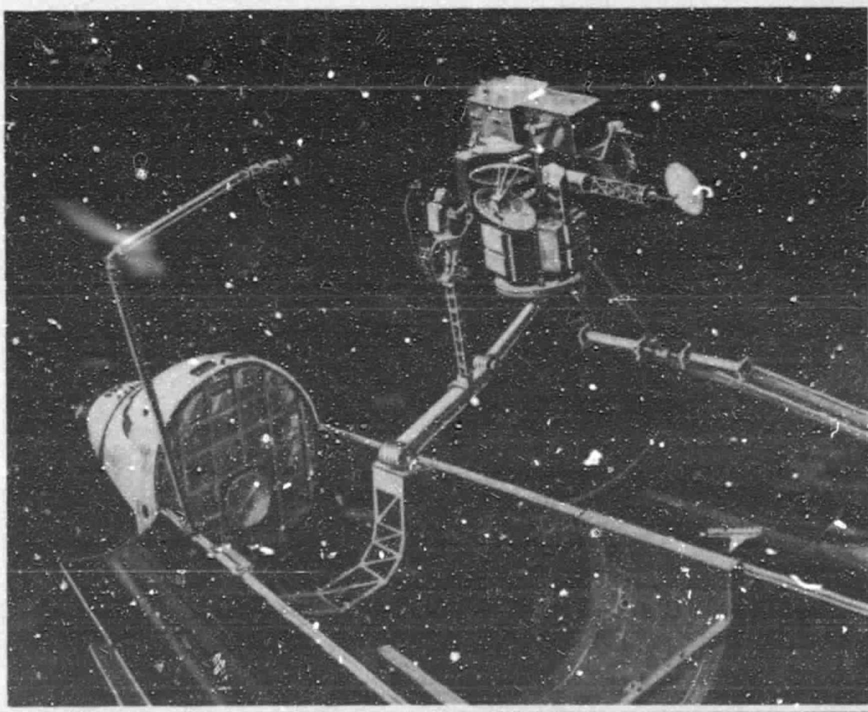
ORBITER-BASED CONSTRUCTION EQUIPMENT STUDY

HPA/DTA technology advancement plan



GRUMMAN AEROSPACE CORPORATION

ORBITER-BASED CONSTRUCTION EQUIPMENT STUDY

HPA/DTA technology advancement plan

prepared for
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ACRONYMS

AFD	=	Aft Flight Deck
CCTV	=	Closed-Circuit Television
DOF	=	Degrees of Freedom
EVA	=	Extra-Vehicular Activity
HPA	=	Handling & Positioning Aid
HPA/DTA	=	HPA Development Test Article
IVA	=	Intra-Vehicular Activity
JSC	=	Johnson Space Center, Houston, Texas
LASS	=	Large-Amplitude Space Simulator (Grumman Facility)
LSS	=	Large Space Structure
MDF	=	Manipulator Development Facility
MFR	=	Manipulator Foot Restraint
MMU	=	Manned Maneuvering Unit
MSFC	=	Marshall Space Flight Center, Huntsville, Alabama
NASA	=	National Aeronautics & Space Administration
OCP	=	Open Cherry Picker
RMS	=	Remote Manipulator System

CONTENTS

CONTENTS (contd)

ILLUSTRATIONS

1 - INTRODUCTION & SUMMARY

A Handling and Positioning Aid (HPA) flight article, with the versatility and adaptability to satisfy a broad variety of operational and mission needs, can be developed with moderate additional technology development beyond the engineering efforts involved in the Development Test Article.

Technology Advancement activities recommended to support the development of a flight system specification for the HPA flight article cover the following:

- HPA Operations - Technology Advancement
  - Developments that relate to enhancing the operational usage of the HPA
- HPA System - Technology Advancement
  - Developments that relate to activities addressing development of an HPA system oriented toward near-term Orbiter applications.

2 - HPA OPERATIONS - TECHNOLOGY ADVANCEMENT

The following sections discuss needed developments to enable the HPA to perform its intended operational functions.

2.1 SATELLITE BERTHING MECHANISM

2.1.1 Task Objective

Establish the requirements for, and develop a preliminary design of, a standard berthing interface between satellites (of up to 60,000 lb) and an Orbiter-based HPA.

2.1.2 Background

To perform the satellite servicing activities of pre-deployment check out and on-orbit maintenance, a satellite should be attached to the Orbiter in a region that provides convenient RMS access and permits deployment of all satellite appendages. This location is provided by the over-the-side position of the HPA arm. However, there is neither an HPA "hand" (that accommodates a standard satellite berthing fixture) nor a standard satellite berthing fixture concept in existence at this time.

2.1.3 Technical Approach

A typical servicing operation would involve RMS capture of a satellite followed by RMS placement of a satellite on the HPA berthing hand. RMS positioning errors (3 degrees of freedom (DOF) in translation and 3 DOF in rotation) and velocity errors (3 DOF in translation and 3 DOF in rotation) will be examined to determine the capture envelope, energy absorption, and speed-of-action requirements of a berthing mechanism on the HPA hand. Loading conditions imposed on the berthing mechanism by EVA servicing operations will be determined for various candidate satellites (e.g., Space Telescope and AXAF). Similarly, loads induced by the Orbiter's Primary and Vernier RCS firings will also be evaluated.

A preliminary design will be developed that meets all of the RMS placement requirements and anticipated loading conditions, and will also incorporate a device to impart a separation velocity to the satellite. The design will emphasize minimum scar weight and cost impact to the satellites. Accommodations for other interface functions (e.g., umbilical connectors) will also be incorporated into the berthing mechanism design.

A model of a first cut flight berthing mechanism will be built and evaluated on a 6 DOF motion simulator (e.g., the Grumman LASS). Evaluation of these simulated satellite berthing operations will support the development of specifications/ requirements for a flight/HPA berthing hand.

2.1.4 Task Output

A specification for a flight hardware Satellite Berthing Mechanism hand for the HPA.

2.2 UMBILICALS FOR FLUID AND ELECTRICAL INTERFACES

2.2.1 Task Objective

Establish the requirements and develop preliminary designs for electrical power/data connections and fluid connections (gases, liquids) between a berthed satellite and the HPA.

2.2.2 Background

A key operational function associated with satellite servicing involves verifying the performance of all satellite subsystems, both before initial deployment and after module replacement during a maintenance service. This verification will normally be performed using an RF link between the satellite and its ground control center. Consequently, hard wire signal connections for satellite checkout aboard the Orbiter are not necessary. However, during checkout or servicing, it may be necessary to provide power to the satellite for thermal control and power conservation reasons; thus a hard wire connection is probably needed between Orbiter and satellite. Similarly, to replenish attitude control or station keeping propellants, gases and/or liquids will have to be transferred from Orbiter to satellite. Umbilical connectors either attached to or incorporated within the HPA offer an effective means for providing these satellite interface needs.

2.2.3 Technical Approach

Fluid and electrical interface needs will be determined for a range of candidate satellites potentially requiring deployment or servicing via the HPA. The coupling modes to be examined during the berthing operation are either manual vs motor driven or command vs automatic. After determining the coupling mode most suitable for HPA operations, a preliminary design will be generated. A model of this umbilical will be built and incorporated into the Satellite Berthing Mechanism hand (as appropriate). The umbilical model will be evaluated on a 6 DOF motion simulator in conjunction with satellite berthing simulations. Requirements for a flight umbilical connection will be based on these evaluations.

2.2.4 Task Output

A specification for a flight version of an Umbilical Connection System.

2.3 EVA SERVICE PLATFORM

2.3.1 Task Objective

Establish the requirements and develop a preliminary design of an EVA Service Platform attached to the HPA arm.

2.3.2 Background

Placing an EVA astroworker on the HPA arm offers considerable flexibility for satellite servicing. The unoccupied RMS can be used to deliver tools and/or replacement modules to the work site while work is being performed on the HPA. Another option is to enable a second astroworker to perform service tasks while mounted on the RMS/Manipulator Foot Restraint.

2.3.3 Technical Approach

The mobility requirements of a worker on the HPA arm will be established. Current indications are that 2 DOF in translation are needed: one parallel, and the other perpendicular, to the upper arm of HPA. Transport velocity range and limits of travel will be established. Stiffness requirements will be based upon the worker's needs for performing servicing tasks. The portion of the EVA Service Platform that restrains the worker, holds tools, and provides illumination is an Open Cherry Picker. New components for the EVA Service Platform are the control devices and the mechanism for providing 2 DOF motions. Motion controllers will be on the platform, actuated by the EVA worker. A first cut flight version of an EVA Service Platform will be designed. A working model of this platform preliminary design will be built for use on the HPA/DTA. Evaluation of the design will take place during two-man servicing simulations using a 6 DOF simulator.

2.3.4 Task Output

A specification for a flight version of an EVA Service Platform which would become part of the standard equipment available with a flight-worthy HPA.

2.4 LARGE MASS BERTHING MECHANISM

2.4.1 Task Objective

Establish the requirements and develop a preliminary design of an androgynous berthing device for the HPA to enable handling of large (between 50,000 and 200,000 lb) space objects, such as the space station. The berthing device is to be capable of docking a space station to the Orbiter and space station modules to one another.

2.4.2 Background

The RMS is basically not designed to handle masses over 32,000 lb. However, it can capture and transport large masses and position them within a suitable HPA target zone; but at the end of this post-capture movement, there will be some oscillatory motion. The HPA, therefore, has been designed to perform a "lunge" motion to capture the large mass while held by the RMS. Following HPA capture, the RMS detaches, and the final docking operation is performed by the stiff HPA arm.

2.4.3 Technical Approach

The baseline mission is Orbiter berthing to a station using the lunge capture mode of the HPA. An androgynous Large Mass Berthing Mechanism hand is attached to the end of the HPA arm; a mating device is located on the Space Station. RMS positioning errors (associated with transporting large masses ranging from space station modules to a completed station) will be examined to determine the capture envelope, energy absorption, and speed-of-action requirements needed for the HPA berthing system. A preliminary design of a flight mechanism that meets these requirements will be developed. A working model of this design will be built and tested on a 6 DOF motion simulator, wherein the simulator will represent RMS characteristics. Following HPA capture, a large mass element containing a docking mechanism will be exercised to verify the HPA's ability to dock two large masses. The HPA berthing mechanism's effectiveness will be noted and potential improvements evaluated during the test program.

2.4.4 Task Output

A specification for a flight version androgynous Large Mass Berthing Mechanism hand for the HPA.

3 - HPA SYSTEM - TECHNOLOGY ADVANCEMENT

3.1 OBJECTIVE

Develop the preliminary design of an HPA flight article responsive to near-term operational needs of the Space Shuttle.

3.2 BACKGROUND

The initial OBCES study established requirements and generated concepts for an HPA flight article based upon a broad spectrum of potential future applications. The validity of these requirements and concepts needs to be reviewed in the light of near-term operational needs of the Orbiter. An HPA concept for near-term use needs to be identified and further developed in terms of a preliminary design. The extent of evolutionary growth that could practically be built into the design also needs to be assessed.

3.3 TECHNICAL APPROACH

HPA requirements will be established for two Orbiter-based operations:

- Upper stage/payload mating
- Satellite servicing.

Upper stages that will be evaluated include the Wide-Body Centaur, Teleoperator Maneuvering System (TMS), Inertial Upper Stage (IUS), and the Mark II (a Multi-Mission Spacecraft (MMS) propulsion derivative). Representative payloads that could be delivered by these upper stages on a single Orbiter launch will serve to identify the range of masses/inertial combinations supported by the HPA arm. The servicing of large satellites, such as the Space Telescope (ST) and the Advanced X-Ray Astronomy (AXAF), will also identify mass/inertial combinations to be considered.

Stiffness requirements for the HPA arm will be established, compatible with the range of masses/inertial combinations identified. This will include further evaluation of the Orbiter's Primary and Vernier RCS control implications (as affecting appropriate dynamic frequency separation) upon the stiffness needs of the HPA arm. Additionally, the over-the-side position of the HPA and the mass/inertial combinations it would support will be evaluated in terms of the Orbiter's control capability, and the off-axis geometric/mass combination's affect on the Orbiter control system logic.

Loading conditions imposed on the HPA will be identified and trades conducted of Orbiter control implications on HPA stiffness needs and weight. The trade studies will identify the appropriate Orbiter control conditions and the HPA's stiffness characteristics needed for operational compatability.

A re-evaluation of the degrees of freedom in the HPA arm, and their respective joint motions, will be conducted as appropriate to near-term Orbiter usage. Additionally, the issue of longeron vs cradle stowage of the HPA arm during launch will also be evaluated. This issue imposes a need for an additional degree of freedom at the HPA elbow and also additional structural support (beyond the cradle that is needed to develop the HPA's stiffness). Following an assessment of these factors, their requirements, and implications, a preliminary design will be developed that satisfies the identified operational needs.

The preliminary design will evaluate the HPA joint drive elements (electric motors, gear boxes, etc.) and the availability of applicable flight qualified equipment. Design studies will be conducted of motor/gear actuator approaches that could be integrated into a single compact/efficient joint housing. This will include considerations of stiffness, drive power, and thermal implications affecting each joint of the arm. A design for the arm structure will be developed which considers use of composites as well as approaches for low weight transition fittings from metal to composite structure.

A cradle design will be developed to provide the requisite stiffness in the HPA arm, and to support the HPA arm during launch (if this is shown to be the preferred support approach). Additionally, an HPA arm emergency jettison system design will be developed to enable closure of the Orbiter's cargo bay doors in the event of failure or jamming of the HPA arm.

Requirements for electrical/electronic components to provide power and control of the HPA will be reviewed, and preliminary designs developed, in terms of equipment needs and mounting locations (HPA arm tubes, cradle, etc.). Similarly, controls and display requirements will be reviewed and methods of implementation assessed. This will include assessment of Orbiter integration implications of Aft Flight Deck mounting vs suitcase adaptation, simplification of HPA control operations (e.g., multiple drive vs single joint), and desirable design inputs from control/display operations of the HPA/DTA.

3.4 OUTPUT

A preliminary design and flight system specification for the HPA flight article responsive to near-term needs of the Space Shuttle.

4 - TECHNOLOGY ADVANCEMENT SCHEDULE

A schedule for the activities described in Sections 2.0 and 3.0 is shown on Fig. 1.

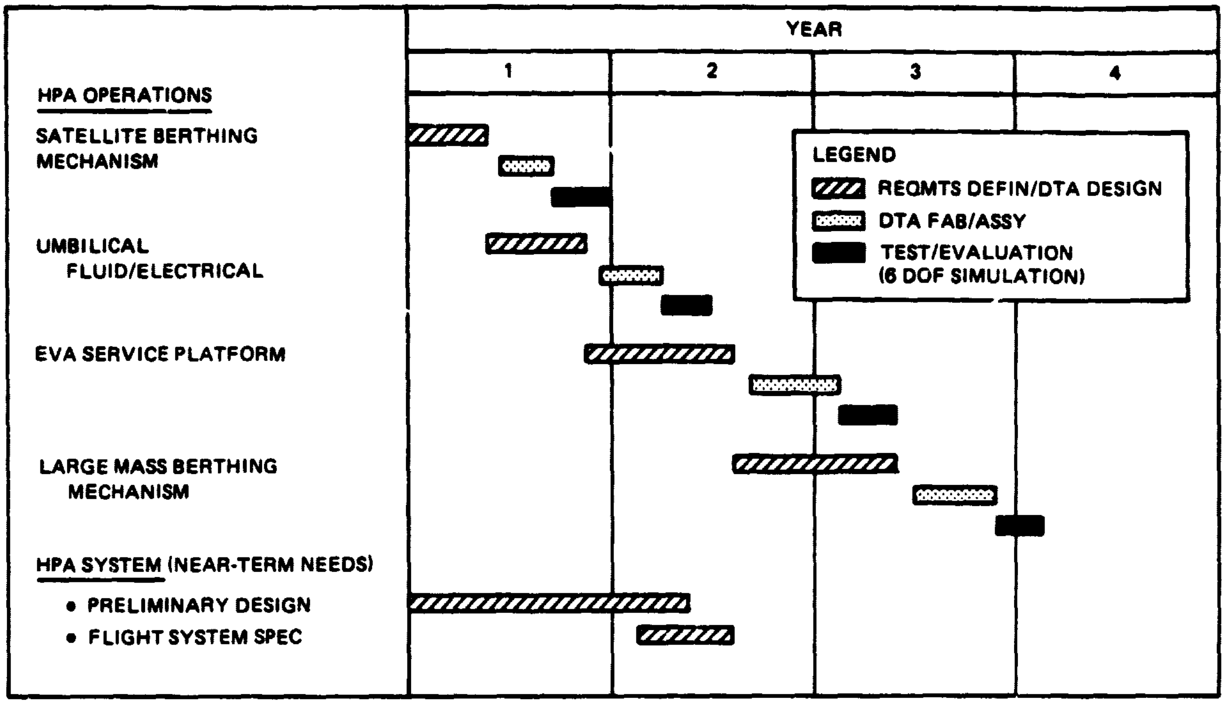

Fig. 1 Technology Advancement Schedule