TECHNICAL LETTER PID-IP&MP-101

(NASA-CR-161210) LOW GRAVITY FLIGHT COMPLEMENT DATA Final Report (Teledyne Brown Engineering) 8 p HC A02/MF A01 CSCL 22A

N79-22173

Unclas G3/12 25111

TELEDYNE BROWN ENGINEERING

TO: Ed Valentine, JA61

FROM: Harry C. Crews, Jr.

SUBJECT: Final Report on Low Gravity Flight Complement Data

DATE: March 30, 1979

TASK: Para. 2.5, Mod. 5
CONTRACT NUMBER NAS8-32711

This technical letter constitutes the final report on work performed under Para. 2.5, Mod. 5 of Contract Number NAS8-32711 and forwards the documentation produced under this task. In addition to the documents described herein and enclosed, Materials Experiment Assembly (MEA) and Materialwissenschaftliche autonome Experimente unter Schwerelosigkeit (MAUS) requirements were furnished for a short carrier design concept developed under a separate contract. That concept was adapted for MEA and MAUS and used in a study on Drop-In Payload opportunities performed under Para. 2.2, Accommodations Assessment, NAS8-32711.

1.0 DOCUMENT DESCRIPTIONS

Work performed under this task has resulted in the production of 3 documents which contain both redundant and unique subject matter. These documents are written for different purposes but supplement each other in the description of the requirements for Low Gravity Flight Complements.

1.1 Design and Performance Requirements for Materials Processing Facilities (MPF) Cargo Bay Carrier

This document describes the structural and mechanical design and performance requirements for a Space Transportation System (STS) carrier which will accommodate essentially self supporting low-g MEA and MAUS facilities.

A brief description of experiment requirements in terms of equipment description, mass properties, access, and installation constraints is given in terms of parameters which affect structural and mechanical design of the carrier primary structure. The accommodations to be provided to the experiment facilities by the carrier are expressed in terms of design loads, mounting provisions, thermal interfaces, and utility interfaces. Specifications and guidelines which govern the interfaces of the experiment facilities and the MPF carrier with the STS are cited in terms of Orbiter/payload structural attachments, structural and dynamic load constraints, utility interfaces, material requirements, safety requirements, thermal requirements, and hardware design standards. Requirements for handling and transporting equipment for the MPF carrier are also established.

1.2 Mission Requirements For An MPF Carrier Assembly

This document defines the mission requirements to accommodate an MPF carrier assembly which includes essentially self-supporting MEA and MAUS experiment facilities. It establishes a framework and description of all known STS mission requirements to fly the MPF carrier assembly with its MEA and MAUS experiment facilities including STS resources and interfaces, flight operations, ground operations, and pre-flight analysis requirements.

1.3 MEA/MAUS Flight Implementation Requirements

The purpose of this document is to define the requirements for implementation of the MEA and MAUS flight aboard an early Shuttle Orbiter mission to gain experience in low accleration materials processing prior to Spacelab-3 (SL-3). It defines the mission objectives, outlines a technical plan, and presents a project schedule in order to meet a December 1980 launch date.

2.0 MPF CARRIER CONCEPT DESCRIPTION AND REQUIREMENTS SUMMARY

Since the MEA and the MAUS experiment facilities are virtually autonomous, the concept of an MPF carrier which provides structural support and structural interfaces with the Orbiter offers advantages in reducing integration effort and simplifying the experiment/Orbiter interfaces. Design requirements identified during this task include the definition of all necessary interface hardware between the MEA/MAUS facilities and the STS to provide the required accommodations for the facilities. The interface hardware include:

- Facilities Carrier
- Ground Handling Equipment
- Mission Peculiar Equipment (MPE).

Operational procedures, constraints, etc. defined for the mission, include:

- Integration
- Ground Operations
- Flight Operations
- STS Interfaces.

2.1 Systems

This section describes the hardware elements and systems, other than STS furnished equipment and systems, which are necessary to implement the flight of the MEA and MAUS experiment facilities. These facilities will furnish their own power, thermal radiators, and process control functions. Minimal amounts of power and communication may be required for Caution and Warning (C&W), Turn-on, and emergency Turn-off from a control switch panel mounted in the Aft Flight Deck (AFD) and hard wired to the experiment facilities in the payload bay. The integrated MPF carrier assembly with experiment facilities attached may be mounted in the payload bay at any longitudinal (x-coordiante) position, subject only to the availability of space, total mission c.g., constraints, and available shuttle trunnion and keel fitting attach points.

2.1.1 MEA

The MEA is being designed to accommodate hardware developed by the Space Processing Rocket (SPAR) Project. Some modifications to SPAR hardware are required for the MEA applications. Since MEA is being designed for as many as ten flights, a number of space processing experiments can be carried out in a timely and cost-effective manner. The MEA facility will provide mounting interfaces for SPAR and other space processing hardware and will provide experiment support functions, which include thermal control, power distribution control, batteries for primary power, and data acquisition formatting and recording. In addition, 3 single-axis low-g accelerometers will be included to measure the accelerations during the flight. This will provide useful diagnostic information to the experimenters, as well as assess the capability of the Shuttle to perform low-g experiments.

The MEA configuration includes six bays. Four of these bays are especially designed to accommodate experiments. The other MEA bays contain subsystems that provide MEA its own power, data management system (including a data recorder), low-g accelerometer system, thermal control system, and storage tank for consumables such as gases and liquids. The MEA is designed to operate in an automatic mode independent of the Shuttle. However, on/off and safing commands will be operated by the crew from the controls in the AFD. It is required that the crew voice record MEA on and off events which are crew-actuated.

2.1.2 MAUS

MAUS is a program sponsored by the Republic of West Germany for the performance of materials processing experiments in self-supporting automated facilities using the National Aeronautics Space Administration (NASA) Get Away Special (GAS) concept. The MAUS payload will consist of 3 standard GAS containers (5 ft^3). The containers will be operated independently. The MUAS payload will be highly autonomous, containing its own power supply, thermal control and data management system. Since the MAUS experiments will be operated in an automatic mode they need only one on-off command from the Shuttle.

2.1.3 MPF Carrier Structure

The carrier accommodates the MEA and MAUS experiments. Accommodations include structural support to meet the Orbiter environment when the Experiment Facilities/Carrier assembly is positioned at any primary trunnion attachment position where associated keel fittings are available in the same x-plane.

2.1.4 Command and Control Cable System (MPE)

MEA and each of the MAUS experiments require circuit interfaces for these functions:

- Standby power on/off control and response indication
- Operating power on/off control and response indication
- Emergency power on/off shutdown control and response indication
- Dually redundant C&W signals and safing commands, if required.

Routing provisions and brackets are provided by the carrier for two separate wire bundles of up to 20 shielded pairs each. Actual cable design will depend upon individual experiment requirements.

2.1.5 Control and Response Panel

The functions listed above may be accomplished by circuits wired directly to the government furnished standard payload switch panel on the AFD for manual operation or to the Orbiter Multiplexer Demultiplexer (MDM) (PF1 or PF2) for control through the General Purpose Computer (GPC) and the Orbiter mission station keyboard. The standard switch panel is already available in the STS program for use by payloads requiring switch functions from the payload station (Panel L12) on the AFD.

2.1.6 Command and Response Software for Orbiter GPC

If the Orbiter mission station keyboard is used for switch and response functions, minimal software is required to add command and response functions to the command list. No more than 12 discrete commands are needed for MEA and MAUS with 12 discrete responses. Four commands and four responses of this number are C&W (if required) and safing command functions and must be dually redundant. The actual number of commands and responses will depend upon particular experiment requirements.

2.1.7 MPF Carrier Vent Lines (MPE) - if required

MEA and MAUS facilities provide their own batteries and pressurized fluids which generate the following gases: helium, air, oxygen, hydrogen, and argon. Although the quantities of these effluents are predicted to be small, vent lines may be required if payloads sensitive to these gases are located in the immediate vicinity of the MEA/MAUS experiments. The routing and length of vent lines depend upon the location of the MEA/MAUS experiments relative to Orbiter vent interfaces.

2.2 Mission Operation and Data Management

This section summarizes the requirements for flight operations, analytical integration, and physical integration for flight implementation of the MEA and MAUS experiment facilities. The virtually autonomous operation of the MEA and MAUS experiment facilities and the use of the MPF carrier concept to minimize STS interfaces simplify the requirements for flightit operations and integration activities.

2.2.1 Flight Operations Requirements

The requirements for flight services and equipment are summarized below.

2.2.1.1 Orbit, Attitude, and Accelerations - There are no orbit restrictions except those determined by the necessity to maintain low-acceleration (5 x 10^{-4}g) and provide an attitude which allows the experiment radiators to dissipate heat. The duration of each experiment and attitude requirements for thermal dissipation are summarized in the MPF Experiment Timeline table.

MPF EXPERIMENT TIMELINE

EXPERIMENT	OPERATION DURATION	THERMAL RADIATOR REQUIREMENT
MLR	14 hr	Radiator view of Sun +
Isothermal Furnace		Earth albedo ≤ 14 min total
		Sun only ≤ 8 min
Gradient Furnace	24-30.5 hr	
Acoustic Levitator	1 hr	Deep space view
MAUS Facilities	2 hr	Deep space view

2.2.1.2 Crew Involvement - The crew is required to activate MEA and MAUS experiments when the conditions above are established, to observe indicator lights verifying activation, to observe C&W lights and/or alarms, to execute safing command switch functions, and to deactivate the experiment facilities at the end of the experiment time. Such action should be annotated on the voice channel within ± 0.5 sec of the time of execution.

2.2.1.3 STS Equipment/Services - A minimum of STS equipment and services is required.

2.2.1.3.1 Payload Bay Mass and Space Requirements -- The carrier accommodates the MEA with a mass of up to 1000 kg and the MAUS experiment containers with a total mass of up to 600 kg. The total mass of the integrated MPF carrier assembly is approximately 2100 kg. Accommodations include structural support to meet the Orbiter environment when the Experiment Facility/Carrier assembly is positioned at any primary trunnion attachment position where associated keel fittings are available in the same x-plane. The integrated carrier assembly when mounted in the cargo bay shall meet the c.g. constraints of Yo = 0 ± TBD in. and Zo = 380 ± TBD in. The integrated MPF carrier assembly is designed to occupy approximately 1.5 m of Shuttle orbiter payload bay length (Δx). The integrated MPF carrier assembly/orbiter interface design loads shall conform to the requirements of the ICD 2-19001.

2.2.1.3.2 Thermal Interfaces -- The carrier provides view factors of 1.0 for the MEA and TBD for the MAUS thermal radiators with respect to carrier structure, its contents, and the payload bay sidewalls.

The integrated MPF carrier assembly mounting position must not preclude radiating surfaces of payloads facing in the Orbiter +Z direction from having an unobstructed view of space with the minimum view factors of 0.80 for MEA and 0.30 for MAUS.

Orbiter accommodations must not preclude the mounting of experiment facility vent lines to an STS vent system for venting small quantities of gases.

2.2.1.3.3 Command and Control -- MEA and each of the MAUS experiments require circuit interfaces for:

- Standby power on/off control and response indication
- Operating power on/off control and response indication
- Emergency power on/off shutdown control and response indication
- Dually redundant C&W signals and safing commands, if required.

Routing provisions and brackets are provided by the carrier for two separate wire bundles of 20 shielded pairs each. Orbiter interfaces are at Xo 576.

These circuits may be wired directly to the government furnished standard payload switch panel on the AFD for manual operation or to the Orbiter MDM (PF1 or PF2) for control through the General Purpose Computer (GPC) and the Orbiter provided mission station keyboard.

2.2.1.3.4 Data Downlink/Payload Operations Control Center (POCC) -- Voice communication and recording of the execution of switch functions described above is the only data downlink and/or POCC requirement anticipated.

2.2.2 Analytical Integration

The required analysis to ensure compatibility of the completely integrated MPF carrier assembly with the STS system and other payloads assigned to the mission must be performed. In addition to the determination of design details for the interfaces and the documentation of integration requirements, the following analyses must be performed. All of the following analyses should be performed such that results are available to the mission manager approximately 30 days prior to the integrated payload (IPL) Final Design and Operational Review (FDOR).

2.2.2.1 Low-g Analysis - An analysis of the low-g environment must be conducted taking into consideration the Orbiter maneuvers and attitude timeline, Orbiter and other experiment activities timelines, and the assigned location of each experiment relative to Orbiter coordinates. This analysis will determine the compatibility of MEA/MAUS experiments with the projected mission activities.

2.2.2.2 Integrated Payload Compatibility Analysis - This analysis will include the evaluation of overall compatibility of Orbiter activities and experiment activities from the point of view of functional interference, time allocations, STS resource allocations, and both the STS induced and experiment induced environments. This must be based on STS descriptions for this mission and current Experiment Requirement Document (ERD) inputs.

2.2.2.3 Ground Integration Analysis - This analysis will result in the definition of ground integration requirements in sufficient detail to provide the physical integration activity with the basis for the preparation of a physical integration plan. It will define all assembly and connections to be made during the integration process and the verification procedures required by the integrated MPF carrier assembly during Level IV and subsequent integration activities.

2.2.2.4 Structural Compatibility Analysis - This structural analysis will be based upon the structural model of the carrier and the experiment facilities furnished by their developers. It will consist of a couple-mode analysis, taking into consideration the load factors and natural frequencies of the STS, the carrier, the experiment facilities, and the experiments. Its purpose is to confirm the structural design integrity of the integrated MPF carrier assembly and all its elements when mounted in the loaded Orbiter cargo bay.

2.2.2.5 Thermal Compatibility Analysis - Based on the thermal models furnished by the developers of the MEA, the MAUS, and the MPF carrier, a coupled thermal analysis of the integrated MPF carrier assembly will be performed and coupled with the Orbiter and other payload bay contents to provide a prediction of the overall thermal environment for the mission.

2.2.2.6 Experiment Safety and Hazard Analyses - These analyses are provided by the experiment/facilities developers and must include an identification of hazards, an approach to eliminating or controlling the hazards and a definition of hazard control implementation hardware or procedures in accordance with JSC 11123, STS Payload Safety Guidelines Handbook dated July 1, 1976 and The Safety Policy and Requirements for Payloads Using the STS dated June 1976.

2.2.3 Physical Integration

The bulk of the required testing will be performed at pre-level IV by the MEA and MAUS developers. These tests will include:

- Acceptance
- Pre-vibration functional

- Post-vibration functional
- Simulated flight.

MEA and MAUS test support will be provided by MEA and MAUS test personnel through integration at Level IV/III/II/I at the launch site. Consequently, support required by other personnel will be minimal.

The MPF carrier assembly consisting of the MPF carrier, the MEA facility, and the MAUS facilities with installed mission peculiar equipment (cables and brackets) will be integrated and verified during level IV (off-line) operations. The integrated MPF carrier assembly will then be integrated with the remainder of the Orbiter cargo at the appropriate facility which simulates interfaces with the Orbiter in order to verify all interfaces. Under normal circumstances the integrated cargo will be removed from the cargo integration facility by the strongback and placed in a transport canister for transport to the OPF for horizontal installation into the Orbiter. The integrated carrier assembly interfaces with the Orbiter consist of the designated trunnion and keel fittings, MPF vent lines to the Orbiter vent system (if required), and the connection of the command and control cables (2 each) to their Orbiter interfaces. If the Orbiter mission station keyboard is to be used for control and response functions, GPC software will be required to implement these functions. If the Orbiter avionics interface is to be with the furnished switch panel at the payload station (panel L12), appropriate switches and indicators will need to be connected as specified to complete and verify the required control and response functions.

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APPROVED:

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Enclosures