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SPACE EXPERIMENT DEVELOPMENT PROCESS

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This paper describes a process for developing space experiments that utilize the Shuttle. The role of the Principal Investigator is described as well as the Principal Investigator's relation with the project development team.

The paper describes the sequence of events from an early definition phase through the steps of hardware development. The major interactions between the hardware development program and the Shuttle integration and safety activities are also shown. Some lessons learned are listed along with references of potential value to experimenters lacking Shuttle experience.

The presentation is directed to people with limited Shuttle experiment experience. The objective is to summarize the development process, discuss the roles of major participants, and list some lessons learned in our short experience. Two points should be made at the outset. First, no two projects are the same so the process varies from case to case. I only hope to convey some principles here to help you find your way through the "system." Second, my recent experience has been mostly with Code EN/Microgravity Science and Applications Division (MSAD). This presentation is heavily influenced by the system evolving there.

OVERVIEW

- O INTRODUCTION
- O ORGANIZATIONAL ELEMENTS
- O PRINCIPAL INVESTIGATOR ROLE
- O DEVELOPMENT ROLE
- O DEVELOPMENT APPROACHES
- O FLOW CHART AND MILESTONES
- O LESSONS LEARNED
- O REFERENCES

Figure 1

INTRODUCTION

- 0 MANY CATEGORIES EXIST FOR SPACE EXPERIMENTS
  - 0 SCIENCE VS. TECHNOLOGY
  - 0 LARGE VS. SMALL
  - 0 CARRIERS AND LOCATIONS
    - MIDDECK LOCKERS/CABIN ENVIRONMENT
    - MPESS/BAY ENVIRONMENT
    - GAS CANS
    - SPACELAB
    - SPACELAB PALLET
    - ETC.
- 0 DIFFERENT SPONSORS USE DIFFERENT PROCESSES
- 0 MOST EXPERIMENTS ARE COSTLY
- 0 MOST ARE LONG-TIME COMMITMENTS

Figure 2

This introductory slide enumerates some of the variables that a space experiment developer encounters. This is compounded by system and personnel changes that occur at different organizations over the life of a project. It is understandable that each project proceeds through the system differently. On the positive side, there is much documentation available. Many precedents and good examples exist. The fact that many experiments have flown provides assurance that it is possible to succeed.

ORGANIZATIONAL ELEMENTS

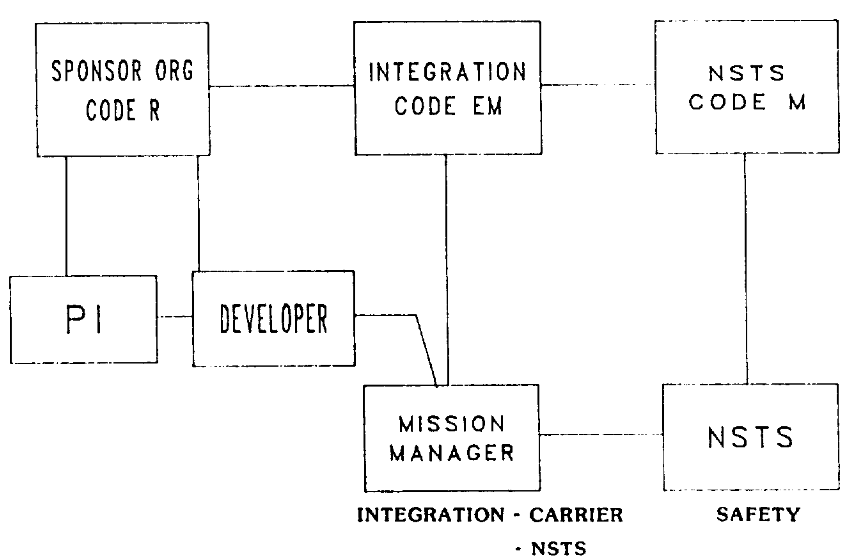

Figure 3

The major organizational elements for an OAST experiment are shown. This should be viewed as a theoretical model. In practice, much informal networking among various elements is needed to accomplish the project.

Headquarters organizations are shown on the top tier. The sponsoring organization usually funds the Principal Investigator (PI) activity separately from the project development activity so the autonomy of each can be preserved. Integration of the experiment into the National Space Transportation System (NSTS) has usually been delegated by Code R to Code EM. They, in turn, fund a mission manager and supporting organization at the Johnson Space Center (JSC), Marshall Space Flight Center (MSFC), or Goddard Space Flight Center (GSFC), to integrate the experiment with the carrier, other experiments, and other elements of the NSTS. Eventually, interaction with the Shuttle operators of Code M and their supporting Centers is required.

PI ROLE AND ACTIVITIES

- RESPONSIBLE FOR THE EXPERIMENTAL IDEA
- EXPLORE IDEA VIA ANALYSIS
- DEMONSTRATE CONCEPT VIA GROUND TEST
- JUSTIFY THE NEED FOR SPACE TEST
- DEFEND THE EXPERIMENT IN REQUIRED "PEER" REVIEWS
- GENERATE REQUIREMENTS DOCUMENT AND EDUCATE DEVELOPERS
- PRESENT EXPERIMENT AT REQUIREMENTS REVIEW
- MONITOR DEVELOPMENT TO INSURE TECHNICAL INTEGRITY
- ANALYZE AND REPORT RESULTS

Figure 4

The Principal Investigator is usually the prime mover for the endeavor. He conceives the idea. He explains it, defends it, and watches over it until the end when he evaluates results and publishes the findings. Some of the principal PI activities are listed.

The task of specifying requirements is always a sensitive one. The PI typically desires state-of-the-art measurements and accommodations to get the best experiment. These requirements drive cost and schedule and in general, affect the ability to develop the system. It is important for the PI and the development team to agree early on appropriate requirements.

DEVELOPMENT ROLE AND ACTIVITIES

- O ITERATE REQUIREMENTS WITH P.I.
- O DEVELOP PROJECT PLAN (COST, SCHEDULE, ETC.)
- O DEVELOP FLIGHT HARDWARE TO MEET REQUIREMENTS
- O KEEP P.I. UP-TO-DATE ON PROGRESS AND PROBLEMS
- O CONDUCT MISSION OPERATIONS
- O COORDINATE MISSION INTEGRATION, SAFETY, MANIFESTING, ETC.

Figure 5

Though the PI, in most cases, is very capable, he may not have the skills, organization, or the desire to develop and integrate the hardware with the space transportation system. That is the contribution of the development organization whose activities are summarized on this slide.

DEVELOPMENT APPROACH OPTIONS

- O USE OR MODIFY EXISTING FACILITY
- O DEVELOP NEW HARDWARE
  - PI TAKES FULL RESPONSIBILITY
    - EXECUTES LITTLE TO MOST OF PROGRAM
    - CONTRACTS FOR REMAINDER
  - PI TAKES SCIENTIFIC RESPONSIBILITY ONLY
    - LETS ANOTHER SOURCE SUPPLY HARDWARE

Figure 6

There are several options for approaching the development of the experiment. A simple approach is to develop an experiment that uses an existing facility. That could give the PI team instant access to an experienced support staff that could carry out the experiment quickly and efficiently. However, that approach constrains the team.

A more comprehensive experiment may require that new hardware be developed. The PI can develop as little or as much as his situation dictates.

SPACE EXPERIMENT DEVELOPMENT MILESTONES

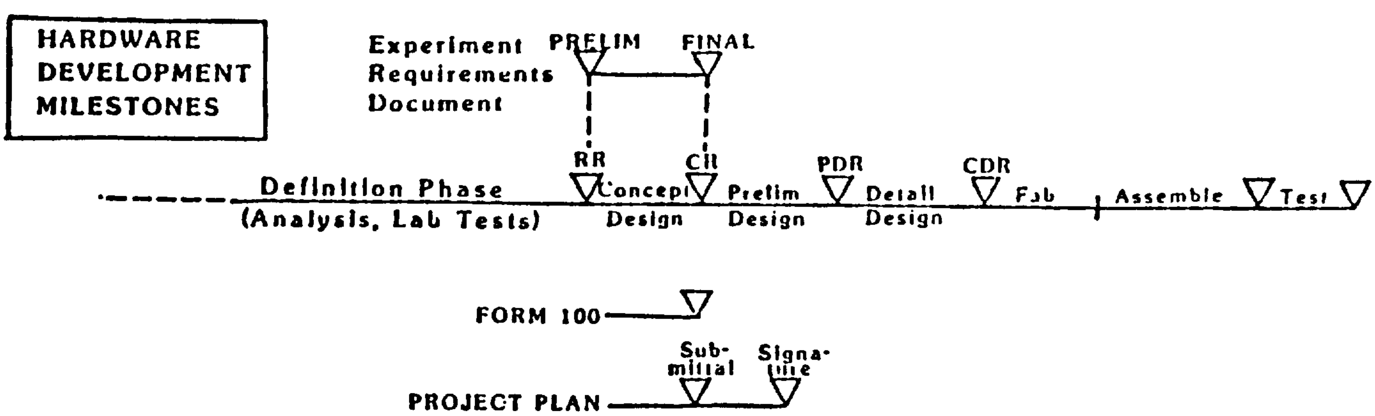

Figure 7

The process starts with a definition phase containing the analysis, breadboarding, and ground testing that spawns the experiment. When the idea is thought to be viable, the PI documents the experiment background, objectives, justification, and engineering requirements so that an engineering team can generate flight hardware design concepts.

A list of the critical technology issues to be addressed in the concept design phase of the program is useful. Cost and schedule information is needed on (a) the concept design phase of the program and (b) the total program. The estimate for (a) will, of course, be more accurate than the estimate for (b). The culmination of this effort is a Requirements Review (RR) involving the PI and hardware development organizations, the sponsoring organization, and any reviewers deemed appropriate.

If the RR is successful and funding is obtained, the project group continues with the conceptual design. Enough engineering should be done in the concept design phase so that an assessment of the feasiblility can be made. The key science and development issues should be demonstrated by test or analysis, thus providing a sound foundation upon which to base a project.

During the concept design phase, the Experiment Requirements Document is negotiated and refined between the PI and engineering organizations so that at the Concept Review (CR), a mutually acceptable document is available.

NOTE: In the Code EN program, RR and CR are called Conceptual Design Review (CoDR) and Preliminary Requirements Review (PRR), respectively.

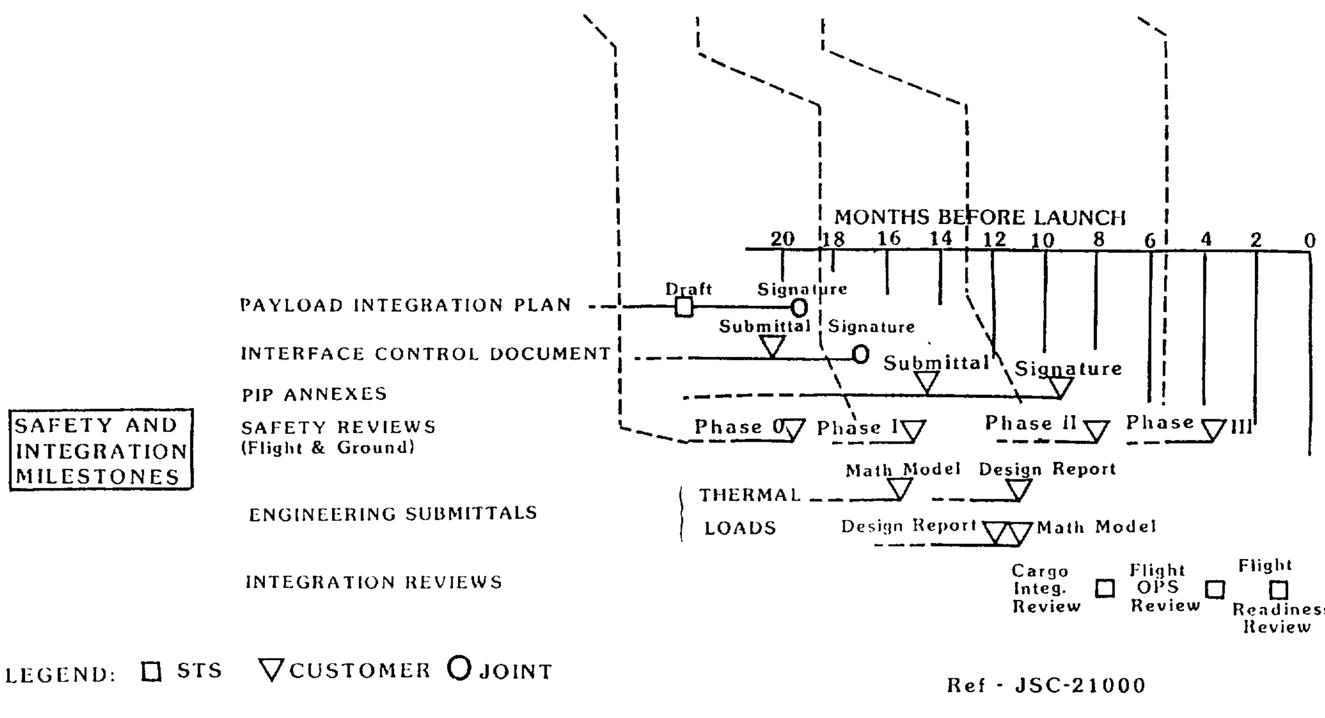

Figure 8A

The Form 100 is necessary to obtain NSTS organization support; it should be processed and signed as the conceptual design takes shape. The Project Office submits a draft to Headquarters which then arranges needed support.

As you complete the conceptual design, submit a cost and schedule estimate for the entire project as part of a project plan. The project plan is an important agreement between the sponsor and the project organization that documents funding, schedule, and other critical project specifics.

Succeeding development activities are shown along the development line. The CR is followed by a design phase leading to a Preliminary Design Review that will enable approval to proceed with detailed design. The Critical Design Review culminates with the approval to fabricate hardware, etc. The typical hardware development milestones are shown in relative to the NSTS integration and safety reviews.

(Note that the scale for NSTS milestones does not apply to the hardware development milestones.)

SPACE EXPERIMENT DEVELOPMENT MILESTONES

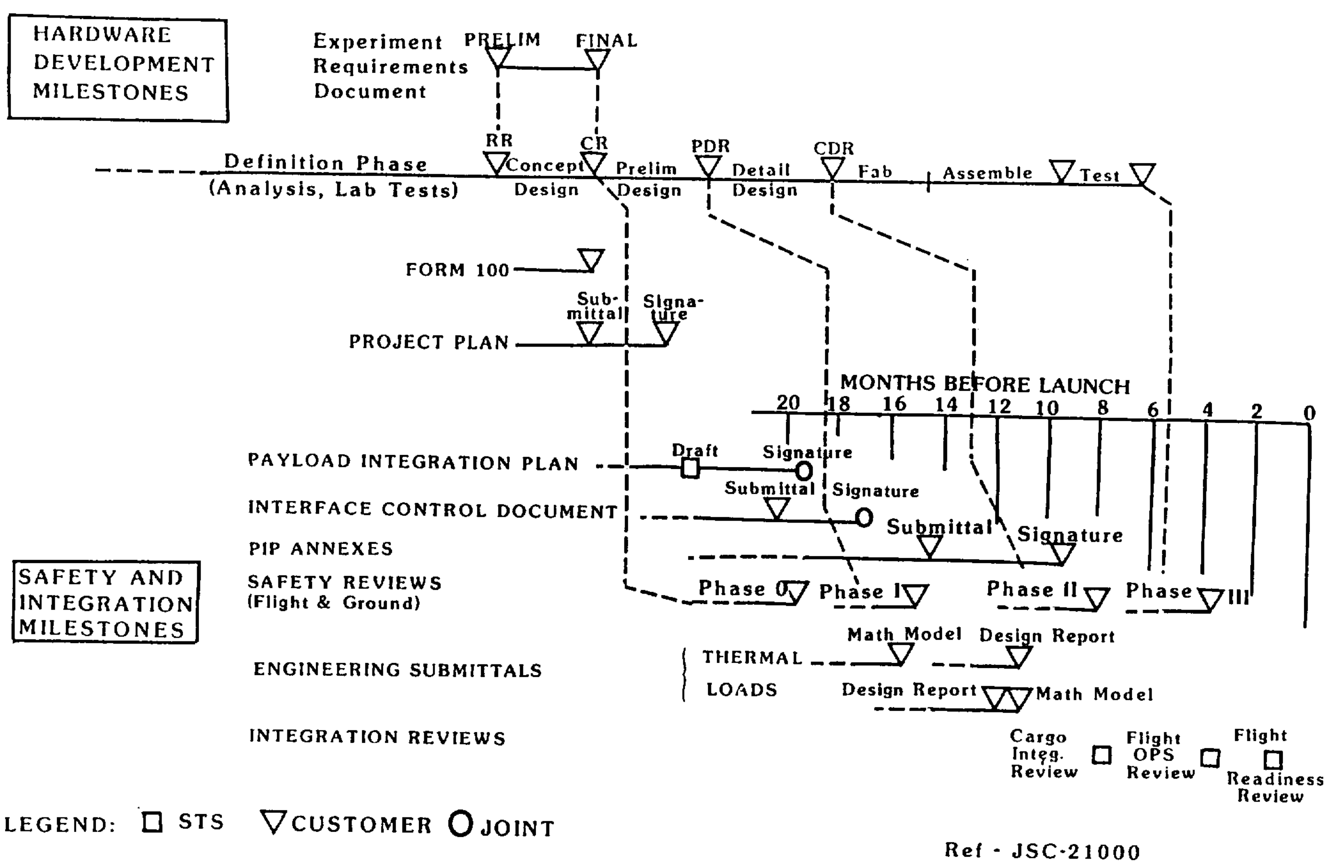

Figure 8B

We at Lewis have some history of space experiments and launch vehicle accomplishments. We are relative newcomers to Shuttle experiment development. In spite of that, we have learned some lessons that may be useful.

The P.I. and the development teams must develop mutual understanding to resolve differences promptly and amiably in order to keep the program on a single, focused path.

Documentation and interpretations are sometimes inconsistent; therefore, investigators must be thorough in exploring questionable areas with NSTS personnel.

Thorough testing at the highest system-level practical can add confidence of success. Such testing can also compensate for shortcuts taken at parts, components, and subsystem levels.

LESSONS LEARNED

- O KEEP THINGS SIMPLE
- O REVIEWS TEND TO IMPROVE BUT COMPLICATE THE EXPERIMENT CONCEPT
- O P.I. AND DEVELOPER MUST DEVELOP MUTUAL UNDERSTANDING
- O PROJECTS ARE LONG AND COSTLY
  (A GENUINELY INTERESTED CORE GROUP IS NEEDED)
- O DOCUMENTATION (AND INTERPRETATION) IS SOMETIMES INCONSISTENT
- O SOFTWARE DEVELOPMENT MUST BE MONITORED CLOSELY
- O THOROUGH SYSTEM-LEVEL TESTING INCREASES PROBABILITY OF SUCCESS

Figure 9

There is an awesome amount of documentation available to guide experiment developers. I have listed only a few that could provide a starting place for the newcomer. The references are available from the following sources:

1. MSFC Spacelab Payload Project Office, Code JA11, Telephone (205) 453-2430.

2. JSC Customer Service Center, Mail Code TC12, Telephone (713) 483-2337.

3. Available from the authors.

A list of key documents from reference 1 is included in this handout along with appendix A of reference 2. The lists identify some of the available documentation.

REFERENCES

1. STS INVESTIGATOR'S GUIDE - MSFC (205) 453-2430

2. SHUTTLE/PAYLOAD INTEGRATION ACTIVITIES PLAN (JSC-21000-IAP) (713) 483-2337

3. FLYING A SCIENTIFIC EXPERIMENT ABOARD THE SPACE SHUTTLE - A PERSPECTIVE FROM THE VIEWPOINT OF THE EXPERIMENTER BY WARREN D. HYPES, NASA LANGLEY AND JOSEPH C. CASAS, OLD DOMINION UNIVERSITY RESEARCH FOUNDATION

Appendix A

Referenced Documents List

Copies of the documents listed below may be obtained by mail or telephone request from:

Customer Service Center
Mail Code TC12
NASA Lyndon B. Johnson Space Center
Houston, TX 77058

713-483-2337

Standard Integration Plans

Standard Integration Plan for Payloads Using Small Payload Accommodations, JSC-21000-SIP-SML

Shuttle/Payload Standard Integration Plan for Spacelab Payload (Generic), JSC-21001-SIP-SLB

Standard Integration Plan for Payloads Using Standard Accommodations (Deployable), JSC-21002-SIP-DEP

Standard Integration Plan for Payloads Using Middeck-Type Payload Accommodations, JSC-21003-SIP-MDK

Standard Integration Plan for Payloads Using Standard Accommodations (Attached), JSC-21004-SIP-ATT

Shuttle/Payload Standard Integration Plan for Payload Specialist Payloads, JSC-21005-SIP-PSP

Shuttle/Payload Standard Integration Plan for DOD Deployable/Retrievable-Type Payloads, JSC-21006-SIP-DOD

Interface Definition Documents

Shuttle/Payload Interface Definition Document for Small Payload Accommodations, JSC-21000-IDD-SML

Shuttle/Payload Interface Definition Document for Middeck Payload Accommodations, JSC-21003-IDD-MDK

Shuttle/Payload Interface Definition Document for Standard Accommodations, JSC-21004-IDD-STD

Miscellaneous Documents

Space Transportation System Customer Accommodations Document, JSC-21000-HBK

Shuttle EVA Description and Design Criteria, JSC-10615

KSC Launch Site Accommodations Handbook for STS Payloads, K-STSM-14.1

Space Transportation System Reimbursement Guide, JSC-11802

NSTS Optional Services Pricing Manual, JSC-20109

Payload Operations Control Center Capabilities Document, JSC-14433

Safety Policy and Requirements for Payloads Using the STS, NHB 1700.7

Implementation Procedures for STS Payloads System Safety Requirements, JSC-13830

Mission Integration Control Board Configuration Management Procedures, JSC-18468

Key Documents & References

Attached Shuttle Payload Carriers
Brochure provided by NASA/GSFC, Greenbelt, MD 20771

Microgravity Science and Applications – Experiment Apparatus and Facilities
Brochure produced by NASA/MSFC Marshall Space Flight Center, AL 35812

Guide to the Life Sciences Flight Experiments Program
Produced by NASA Life Sciences Flight Programs Branch at NASA Headquarters, Washington, DC 20546

User's Guide to Spacelab Payload Processing
Produced by Cargo Projects Office, NASA/KSC, Florida 32899

STS User Handbook
NASA Headquarters, Washington DC 20546

Launch Site Accommodations Handbook for STS Payloads
NASA/KSC Document, K-STSM-14.1

The User's Guide to Spacelab Payload Processing
Brochure provided by NASA/KSC, Florida 32899

Mission Requirements on Facilities/Instruments/ Experiments for STS Attached Payloads (MROFIE)
MSFC JA-447

Payload Flight Equipment Requirements for Safety-Critical Structures
MSFC JA-418

Payload Developer's Guide for Launch Site Operations
KSC IV 0018.0

Spacelab Payload Accommodations Handbook (SPAH)
SLP/2104

Space Shuttle System Payload Accommodations
JSC 07700, Vol. XIV

Safety Policy and Requirements for Payloads Using the STS
NHB 1700.7A

Orbiter Middeck Payload Provisions Handbook
JSC-16536

STS Payload Safety Guidelines Handbook
JSC 11123

POCC Capability Document
JSC-14433

"Flying a Scientific Experiment Aboard the Space Shuttle – A Perspective from the Viewpoint of the Experimenter,"
A Technical Paper by Warren Hypen (NASA/LaRC) and Joseph C. Casas (Old Dominion University Research Foundation, Norfolk, Virginia)

Notes: