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THE PATH TO AN EXPERIMENT IN SPACE
(From Concept to Flight)

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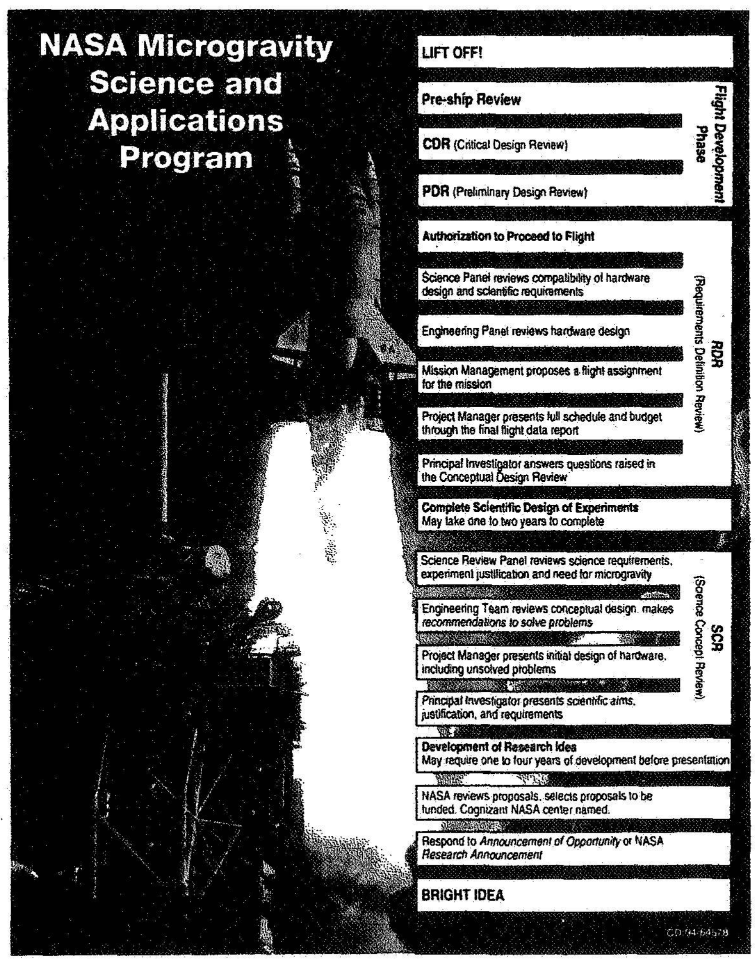

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TIME FROM FLIGHT PI SELECTION TO LAUNCH

NEW HARDWARE

- **GLOVEBOX - 3 YEARS OR LESS**
- **SOUNDING ROCKETS - 3 TO 4 YEARS**
- **GET-AWAY SPECIAL - 3 TO 4 YEARS**
- **MIDDECKS - 5 TO 6 YEARS**
- **USMP - 6 TO 8 YEARS**
- **USML - 6 TO 8 YEARS**

REFLIGHTS (MINOR OR NO MODS)

- **SOUNDING ROCKETS - 6 MONTHS**
- **GET-AWAY SPECIAL - < 1 YEAR**
- **MIDDECKS - 1 YEAR**
- **USMP - 2 YEARS**
- **USML - 2 YEARS**

Key Flight Experiment Phases and Schedule Drivers

Experiment Definition (PI & PS)

- Focus science objectives into experiment concept
- Conduct ground-based program (analysis, 1-g and μ-g tests)
- Determine flight experiment science requirements
- Demonstrate basic experiment feasibility

Flight Experiment Concept Definition (PI, PS, and PM)

- Define engineering requirements and hardware concepts, (size, weight, power, etc.)
- Determine appropriate carrier choice(s)
- Demonstrate technology readiness
- Prepare project plan (schedule, cost, etc.)

Flight Experiment Development (PI, PS & PM)

- Generate final hardware design
- Complete hardware development, assembly, test (performance and qualification)
- Prepare documentation

Key Flight Experiment Phases and Schedule Drivers

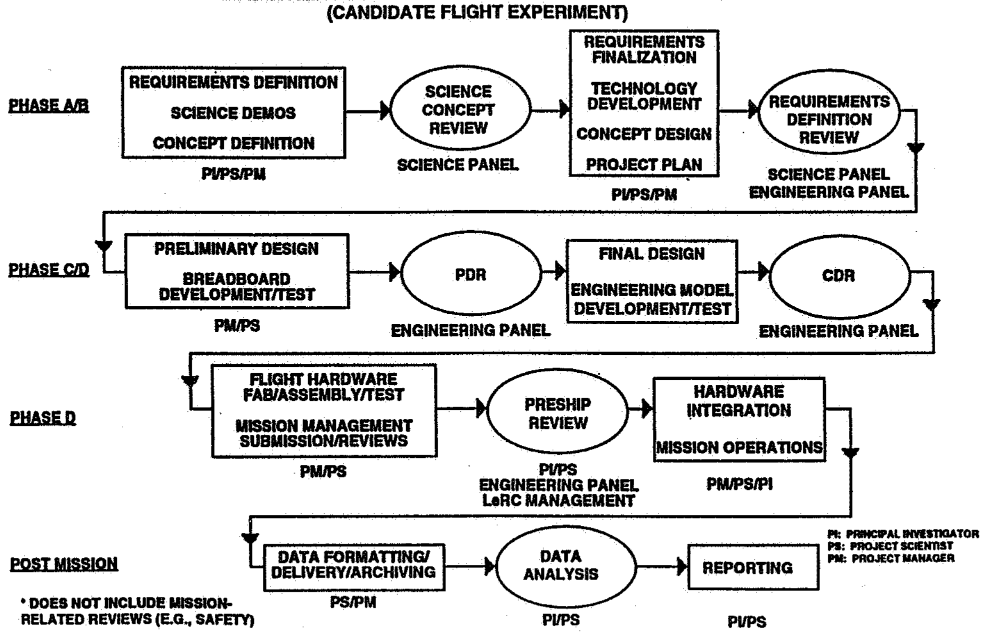
Mission Integration and Operations (PI, PS, PM, & MM)

- Conduct mission planning
- Complete mission, integration and safety reviews
- Complete physical integration
- Complete documentation
- Conduct mission operations

Review, Review, Review, ••••••••••••••••••••••••••••••••••••
Document, Document, Document ••••••••••••••••••••••••••

PI (Principal Investigator), PS (Project Scientist), PM (Project Manager), MM (Mission Manager)

MICROGRAVITY EXPERIMENT DEFINITION/DEVELOPMENT PROCESS*
(CANDIDATE FLIGHT EXPERIMENT)



* DOES NOT INCLUDE MISSION-RELATED REVIEWS (E.G., SAFETY)

DEFINITION AND ENGINEERING DEVELOPMENT PHASE

SCIENCE CONCEPT REVIEW
SCR
▽

REEQUIREMENT
DEFINITION REVIEW
RDR
▽

SCIENCE DEFINITION

- DEVELOP SCIENCE REQUIREMENTS
- PROVIDE JUSTIFICATION FOR FLIGHT
- DEMONSTRATE SCIENTIFIC FEASIBILITY
- IDENTIFY ENGINEERING CONCEPTS
- IDENTIFY HIGH RISK DEVELOPMENT ITEMS
- DEFINE THE PLAN TO RDR
- IDENTIFY HAZARDS

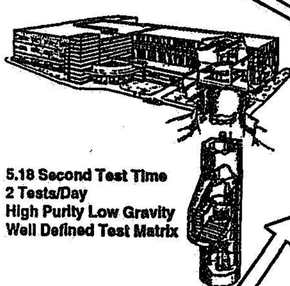
ENGINEERING DEVELOPMENT

- UPDATE SCIENCE REQUIREMENTS
- DEFINE FUNCTIONAL REQUIREMENTS AND CONCEPTUAL DESIGN
- CONFIRM THE FEASIBILITY OF HIGH RISK ELEMENTS
- DEFINE THE BUDGET (INCLUDING CONTINGENCY) AND SCHEDULE
- PREPARE PHASE O SAFETY PACKAGE

▽ HQ CONTROLLED; REQUIRES APPROVAL BEFORE PROCEEDING

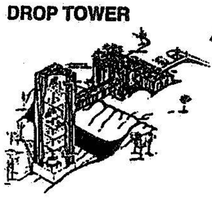
GROUND-BASED REDUCED GRAVITY RESEARCH FACILITIES

ZERO GRAVITY RESEARCH FACILITY



5.18 Second Test Time
2 Tests/Day
High Purity Low Gravity
Well Defined Test Matrix

DROP TOWER



2.18 Second Test Time
12 Tests/Day
Exploratory Tests
Large Test Matrixes

- UNIQUE LABORATORIES FOR THE DEVELOPMENT AND SUPPORT OF RESEARCH AND TECHNOLOGY VALIDATION ACTIVITIES
- VALUABLE SOURCE OF DATA IN THE PI FLIGHT EXPERIMENT DEFINITION PROCESS
- IMPORTANT TEST FACILITIES IN THE FLIGHT HARDWARE DESIGN, DEVELOPMENT AND TEST PROCESS

DC-9, KC-135, LEARJET AIRCRAFT

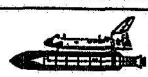
18-22 Second Test Time
Large Experiments
Operator Interaction
Large Test Matrix

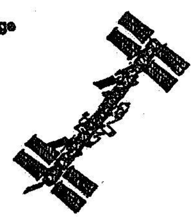
Optimize Designs
Define Measurement Requirements
Refine Experiment Timelines, Procedures

Develop Low-G Specific Technologies/ Techniques
Confirm Benefits of Flight
Acquire Fundamental Knowledge

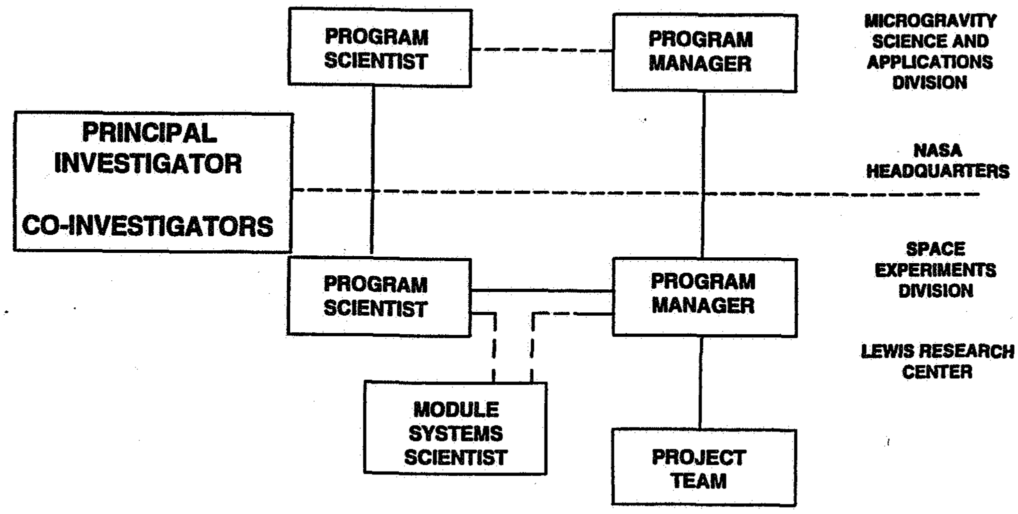
STS, ELV EXPERIMENTS
SPACE STATION PRECURSOR EXPERIMENTS

1994 — 2000





PROJECT ORGANIZATION



PRINICIPAL INVESTIGATOR / CO-INVESTIGATORS

RESPONSIBILITIES

- ENSURE A HIGH SCIENTIFIC RETURN FROM THE FLIGHT PROJECT
- PROVIDE ANALYSIS AND REPORTING OF THE FLIGHT EXPERIMENT RESULTS IN A TIMELY MANNER

SOME SPECIFIC DUTIES

- PREPARE AND MAINTAIN THE SCIENCE REQUIREMENTS DOCUMENT
- RECOMMEND AND PROVIDE EXPERIMENT HARDWARE AND TECHNOLOGIES WHEN APPROPRIATE
- CONDUCT ANALYSES AND GROUND-BASED EXPERIMENTS TO REFINE EXPERIMENT TEST PARAMETERS, DATA REQUIREMENS, AND OPERATING PROCEDURES
- CONDUCT ANALYSES TO SUPPORT EXPERIMENT DESIGN
- REVIEW AND APPROVE EXPERIMENT DESIGNS AND TECHNOLOGIES
- REVIEW AND APPROVE HARDWARE PERFORMANCE TESTS
- SUPPORT CREW AND GROUND OPERATIONS TRAINING
- PARTICIPATE IN EXPERIMENT OPERATIONS
- PARTICIPATE IN FORMAL EXPERIMENT REVIEWS
- ANALYZE THE FLIGHT DATA AND REPORT THE RESULTS IN THE SCIENTIFIC LITERATURE

PROJECT SCIENTIST

RESPONSIBILITIES

- ENSURE THE SCIENTIFIC INTEGRITY OF THE EXPERIMENT
- REPRESENT THE PI IN HIS INTERACTIONS WITH THE PM AND OTHER NASA PERSONNEL
- FACILITATE THE TIMELY ANALYSIS AND DISSEMINATION OF SCIENTIFIC RESULTS

SOME SPECIFIC DUTIES

- ASSIST THE PI IN PREPARING AND MAINTAINING A SCIENCE REQUIREMENTS DOCUMENT
- COLLABORATE WITH THE PM IN GENERATING FUNCTIONAL/SYSTEM/TECHNOLOGY REQUIREMENTS FROM SCIENCE REQUIREMENTS
- ASSIST THE PM IN DEFINING AND SELECTING CONCEPTS AND LEVELS OF TECHNOLOGY
- SUPPORT THE PI IN EVALUATING CONCETPS, DESIGNS, AND OPERATING PROCEDURES
- PARTICIPATE IN ALL PROJECT REVIEWS AND ASSIST THE PI AT ALL FORMAL REVIEWS
- MONITOR AND ASSIST IN ASSESSMENT OF ALL HARDWARE PERFORMANCE TESTS
- MONITOR PI ACTIVITY TO ENSURE FULFILLMENT OF REPORTING REQUIREMENTS
- ASSIST THE PI IN RESEARCH TESTS CONDUCTED IN NASA FACILITIES
- RESOLVE DISPUTES BETWEEN PI AND PM OR REFER DISPUTES TO PROGRAM SCIENTIST

PROJECT MANAGER

RESPONSIBILITIES

- ADMINISTER ALL PROJECT MANAGEMENT FUNCTIONS NECESARY FOR THE SUCCESSFUL PERFORMANCE OF THE EXPERIMENT
- ENSURE THE DELIVERY OF HARDWARE CAPABILITIES AND OPERATIONS TO SATISFY THE EXPERIMENT SCIENCE REQUIREMENTS

SOME SPECIFIC DUTIES

- PREPARE AND MAINTAIN THE PROJECT PLAN
- MONITOR AND REPORT PROJECT COST AND SCHEDULE STATUS
- DIRECT THE DEVELOPMENT OF EXPERIMENT FUNCTIONAL REQUIREMENTS AND CONCEPTS
- MANAGE THE DESIGN, DEVELOPMENT, PRODUCTION, AND TESTING OF THE EXPERIMENT HARDWARE (ALL PHASES)
- PREPARE ALL NECESSARY DOCUMENTATION REGARDING SAFETY, INTEGRATION, AND OPERATIONS
- PROVIDE CREW AND GROUND OPERATIONS TRAINING
- SUPPORT THE PI DURING EXPERIMENT OPERATIONS
- PARTICIPATE IN ALL PROJECT REVIEWS

SCIENCE REQUIREMENTS DOCUMENT

I. INTRODUCTION: SUMMARY DESCRIPTION OF EXPERIMENT; THE KNOWLEDGE SOUGHT AND ITS VALUE; AND THE JUSTIFICATION OF THE NEED FOR THE SPACE EXPERIMENT

II. BACKGROUND: SUMMARY OF RELATED RESEARCH, PAST AND CURRENT; RELATIONSHIP OF PROPOSED EXPERIMENT TO THE SCIENTIFIC FIELD, APPLICATIONS OF RESEARCH RESULTS

III. JUSTIFICATION FOR CONDUCTION THE EXPERIMENT IN SPACE: LIMITATIONS OF GROUND-BASED TESTING (NORMAL GRAVITY, DROP TOWERS, AIRCRAFT); LIMITATIONS OF MODELING; SUMMARY OF SPACE-BASED EXPERIMENTS

IV. EXPERIMENT DETAILS: EXPERIMENT PROCEDURES; REQUIRED MEASUREMENTS; GROUND-BASED TEST PLAN, INCLUDING FUNCTIONAL TESTING OF FLIGHT APPARATUS; POST-FLIGHT DATA HANDLING AND ANALYSIS

V. EXPERIMENT REQUIREMENTS: EXPERIMENT SAMPLE (FUEL, MATERIAL, FLUID); ATMOSPHERE; TEMPERATURE CONTROL; ACCELERATION LEVEL CONTROLS; TEST MATRIX; IMAGING; MEASUREMENTS; ASTRONAUT INVOLVEMENT; DATA

THROUGHOUT III, IV, AND V EACH REQUIREMENT SHOULD BE JUSTIFIED OR SUBSTANTIATED WITH RESPECT TO THE EXPERIMENT OBJECTIVES.

A TABULAR SUMMARY OF QUANTITATIVE REQUIREMENTS IS A USEFUL FEATURE OF THE SRD.

THE FINAL SCIENCE REQUIREMENTS DOCUMENT

- NASA COMMITS RESOURCES TO FULLY SATISFY REQUIREMENTS (IRONCLAD CONTRACT)
- PI FREEZES SCIENCE UNTIL LAUNCH (3 TO 6 YEARS)

A DOUBLE-EDGED SWORD

THE IDEAL SCR

- WELL DEFINED AND DEFENDABLE SET OF SCIENCE REQUIREMENTS
  - DEFINITIVE TEST MATRIX AMENDABLE TO FLIGHT CONSTRAINTS
  - DEFINITIVE LIST OF EXPERIMENT CONTROL PARAMETERS
  - DEFINITIVE LIST OF MEASUREMENT REQUIREMENTS (TYPES, ACCURACY, RESOLUTION)
- IDENTIFIED TECHNIQUES AND TECHNOLOGIES TO SATISFY REQUIREMENT
  - DEMONSTRATED CAPABILITY (ACCURACY, RESOLUTION)
  - HARDWARE ACCEPTABLE TO FLIGHT CONSTRAINTS
- WELL DESIGNED FLIGHT EXPERIMENT CONCEPT
  - PREDICTED PERFORMANCE WHICH MEETS REQUIREMENTS
  - MANIFEST OPTION WITH REASONABLE RESOURCE MARGINS
- SOUND PROJECT PLAN
  - CLEAR ORGANIZATION RESPONSIBILITIES
  - DETAILED AND REALISTIC PLAN TO RDR

COMMUNICATIONS (PI <--> PS <--> PM)
GROUND-BASED TESTS

FLIGHT DEVELOPMENT PHASE

PRELIMINARY DESIGN REVIEW
PDR

CRITICAL DESIGN REVIEW
CDR

PRE-SHIP REVIEW
PSR

<u>PRELIMINARY DESIGN</u>

- COMPLIANCE WITH SCIENCE & DESIGN REQUIREMENTS
- FUNCTIONAL & INTERFACE REQUIREMENTS
- BREADBOAD TESTING
- ENGINEERING MODEL DRAWINGS

→

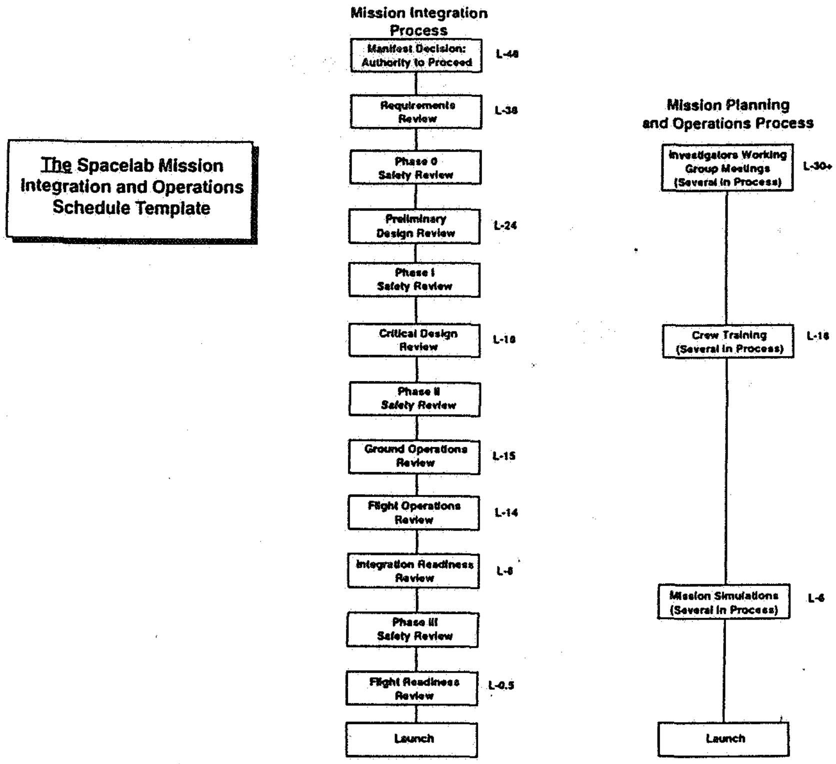
<u>ENGINEEING MODEL</u>

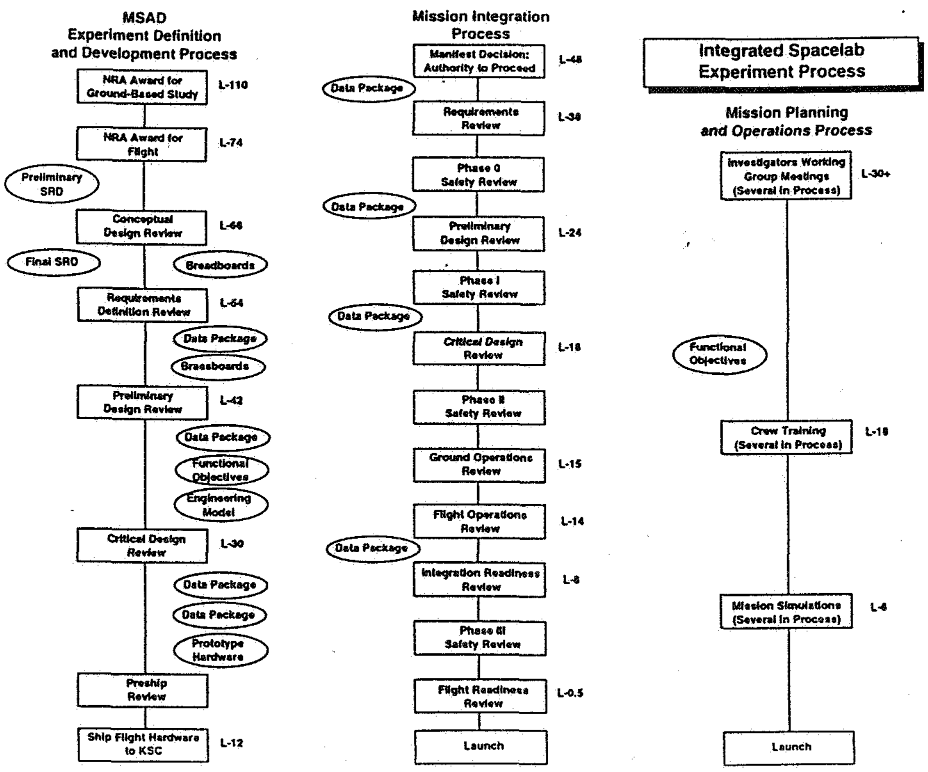
- ENGINEERING MODEL FABRICATION, INTEGRATION AND TEST
- FLIGHT DESIGN
- FLIGHT DRAWINGS (90%)
- INTEGRATION AND TEST PLANNING

→

<u>FLIGHT FABRICATION, INTEGRATION AND TEST</u>

- FLIGHT FABRICATION, INTEGRATION AND TEST
- EXPERIMENT SIMULATIONS


The Spacelab Mission Integration and Operations Schedule Template
Mission Integration Process
Manifest Decision: Authority to Proceed
L-48
Requirements Review
L-38
Phase 0 Safety Review
Preliminary Design Review
L-24
Phase I Safety Review
Critical Design Review
L-18
Phase II Safety Review
Ground Operations Review
L-15
Flight Operations Review
L-14
Integration Readiness Review
L-8
Phase III Safety Review
Flight Readiness Review
L-0.5
Launch
Mission Planning and Operations Process
Investigators Working Group Meetings (Several in Process)
L-30+
Crew Training (Several in Process)
L-18
Mission Simulations (Several in Process)
L-6
Launch


MSAD Experiment Definition and Development Process
NRA Award for Ground-Based Study
L-110
NRA Award for Flight
L-74
Preliminary SRD
Conceptual Design Review
L-66
Final SRD
Breadboards
Requirements Definition Review
L-54
Data Package
Brassboards
Preliminary Design Review
L-42
Data Package
Functional Objectives
Engineering Model
Critical Design Review
L-30
Data Package
Data Package
Prototype Hardware
Preship Review
Ship Flight Hardware to KSC
L-12
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EXPERIMENT COST AND SCHEDULE

- COST AND SCHEDULE ARE HEAVILY DRIVEN BY MANPOWER REQUIREMENTS FOR
  - DOCUMENTATION
  - DESIGN AND DRAWINGS
  - ANALYSIS
  - REVIEWS
- CHANGING REQUIREMENTS ARE A PM's NIGHTMARE
- COST AND SCHEDULE ESTIMATES ONLY BECOME REALISTIC AFTER RDR
- CARRIER CHOICE HAS LARGE IMPACT ON COST AND SCHEDULE
  - DIFFERENT GAS CAN, MIDDECK, USML, USMP REQUIREMENTS
  - DIFFERENT REFLIGHT OPPORTUNITIES
  - UNCLEAR MANIFEST OPPORTUNITIES EARLY IN PROCESS
- COST AND SCHEDULE CAN BE TRIMMED BY DEVELOPING HARDWARE BEFORE PI's ARE AVAILABLE
  - CHOOSE PI's (I.E., SCIENCE) TO MATCH HARDWARE CAPABILITIES
  - UNPROVEN APPROACH (POTENTIAL PROBLEMS WITH PROGRAM GOALS)
- PROCESS FOR SPACE STATION FREEDOM EXPERIMENTS IS STILL EVOLVING (CAN IT BE SIMPLER OR FASTER?)

KEYS TO EXPERIMENT SUCCESS

- EFFECTIVE BALANCE BETWEEN EXPERIMENT COMPLEXITY AND MATURITY OF THE SCIENCE
  - EVOLUTIONARY APPROACH TO RESEARCH
  - WELL POSED HYPOTHESIS
  - REQUIREMENTS CLEARLY NEED DRIVEN
- EXTENSIVE PI INVOLVEMENT
  - CLEAR REQUIREMENTS AND DIRECTION EARLY IN PROCESS
  - REGULAR INTERACTIONS WITH PS AND PROJECT TEAM
  - PARTICIPATION IN MISSION PLANNING AND TRAINING
- EFFECTIVE PROJECT TEAM
  - SOLID PI-PS RELATIONSHIP
  - SKILLED PM
  - DEDICATED, CAPABLE PROJECT MEMBERS
- ADEQUATE PRE-PROJECT EFFORTS
  - GROUND-BASED TESTING
  - EXPERIMENT DEFINITION
- EARLY IDENTIFICATION AND RESOLUTION OF TECHNOLOGY TALL POLES
- EARLY ATTENTION TO MISSION PLANNING

COMMUNICATIONS
PI <--> PS <--> PM <--> MISSION