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THE HUMAN ROLE IN SPACE

By Stephen B. Hall, Georg von Tiesenhausen, and Gary W. Johnson
Program Development

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16. ABSTRACT

This report describes a limited Marshall Space Flight Center in-house study on the human role in space. This study was performed during 1980 and its procedures and results were only available in chart form. Since the methodology and findings could be of interest to a larger circle of people the report form was chosen as an efficient way to disseminate the study results for future reference. It should be noted that the mission model used in this study has changed; however, the approach taken and the general conclusions have remained valid.

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I. INTRODUCTION

The beginning of the Space Shuttle era in the early 1980's introduces efficient and frequent access to space. This economy of space access has to be matched with an equivalent economy of space mission activities.

In view of the numerous space activities planned beginning in the mid-1980's and beyond, the question of extreme economy in performance, life cycle, and cost of these missions is of foremost importance. This has generated a need to define specific requirements for the future human role in space with the overall goal to achieve an optimum mix between human and machine.

Throughout the past decades of space flight, humans have set precedents of extraordinary accomplishments in space. The Apollo and Skylab programs were major milestones where human intervention and performance were vital to mission success. However, this era ended seven years ago with the joint Apollo-Soyuz mission. Since then only automated spacecraft continued to provide communication links, environmental and scientific information, and to explore the solar system. This constituted a temporary hiatus in manned spaceflight in the United States, but not in the U.S.S.R. We needed the respite to concentrate attention on the Shuttle which was a bold committment to manned spaceflight.

With the advent of the Space Shuttle, NASA aims at a balanced space program that will include both manned and automated space missions with the goal of approaching a proper mix between humans and machines for each mission. This requires a rational approach in utilizing the unique human capabilities in space for the greatest economy in carrying out planned missions.

II. BACKGROUND

In 1980 the Director of Advanced Programs in the Office of Space Transportation Systems noted that:

"In considering our current advanced projects line-up, it has become apparent that we will quite likely be required soon to provide a stronger rationale for the role of man in the evolutionary development of our space capabilities up to and including the permanent manned facilities. At present, we have little systematic data useful toward that objective." [1]

He proceeded to request an in-house analysis that was to systematically address four areas in sufficient depth to support longer range plans. These were:

1) The preferred roles for human beings in each of our projects.

2) A categorization of the functions likely to be best performed by humans in-situ versus humans via teleoperator versus automated remote operations for each of our projects, and in summary.

3) An extraction of the likely implications on support equipment and habitation needs in terms of volume, power, configuration, etc.

4) An assessment of the potential for such needs to be met by growth of the Shuttle and Spacelab versus new habitation modules and vehicles.

Subsequently, additional guidelines [2] pointed out the need for a quantitative assessment of the future human role in space. These were (in abbreviated form):

1) Develop a "strawman" mission model for a 20-year span, based on the current Ten Year Plan FY 1982-91 (with extension to 2000).

2) Develop first-cut project timelines and an overall first-cut timeline for the assumed mission model which will place the functions identified for man versus machine into a schedule relationship.

3) Develop man-hour estimates, skill requirements, etc., to quantify the degree of human involvement in the timelined mission model.

4) From quantitative data pool, generate information relative to number of people, support requirements, other "orbital burden" factors, etc., that would enable us to develop the rationale for permanent manned facilities in LEO and GEO.

Based on these guidelines an in-house study was carried out. The study method procedures and results are described in this report.

III. STUDY OBJECTIVE

The objective of the study is to provide a more solid basis for NASA's future space program planning with an evaluation of the roles of humans and humans supported by machines and a qualitative and quantitative assessment of human involvements in future planned space missions.

IV. STUDY OVERVIEW

The study consists of two parts: a qualitative and a quantitative assessment (Fig. 1):

PART I

Extensive research through applicable study reports and discussions with planning and study personnel resulted in presently envisioned roles of humans in space and a categorization of tasks assigned to either humans, humans/machine, or machines only.

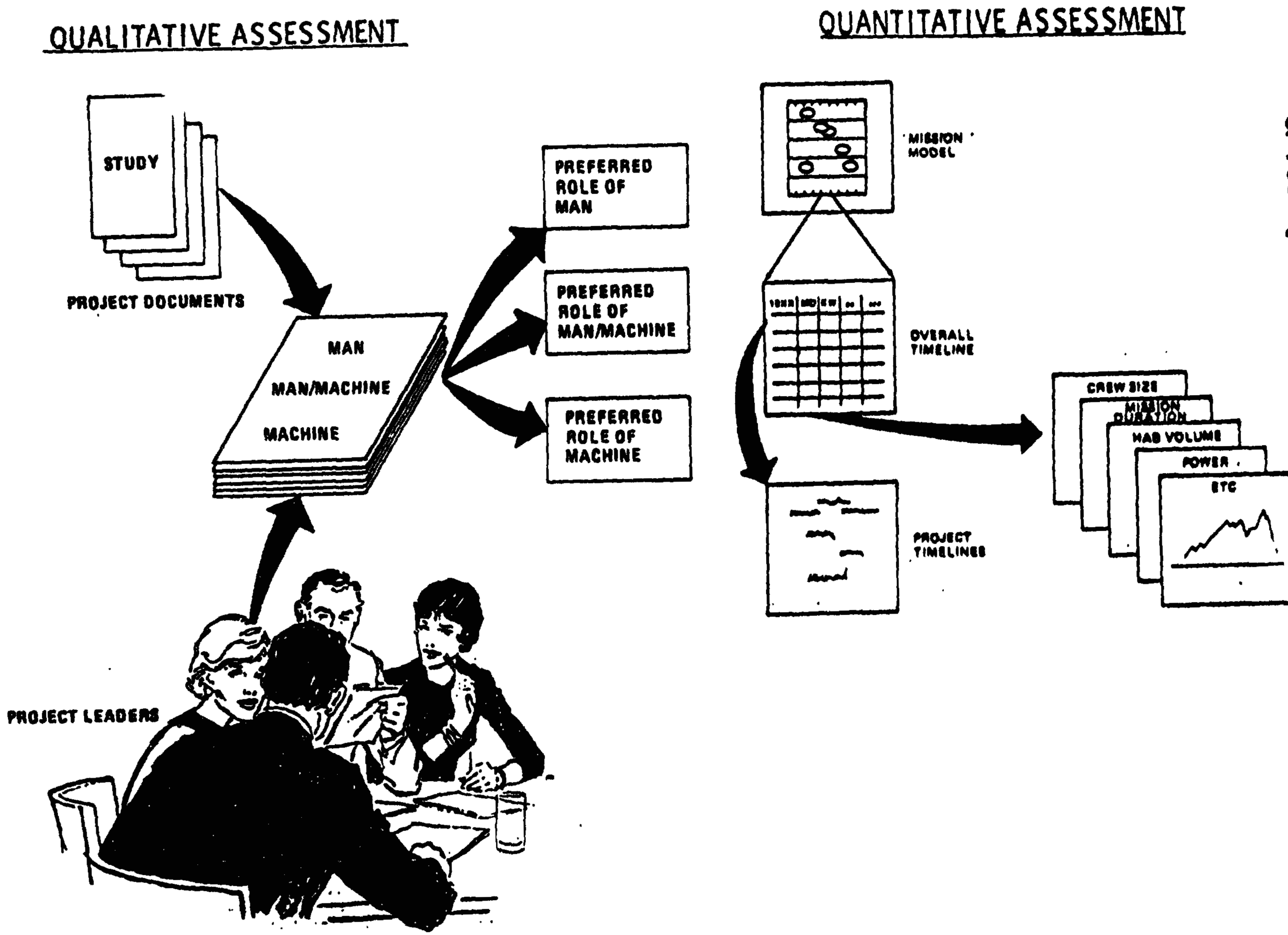

Figure 1. Study overview of man's role in space.

PART II

A mission model was constructed from available data and schedules taken from applicable documents and discussions [3]. Overall timelines and project timelines were generated and crew requirements extracted.

In order to assist in better understanding of the study content, the definitions shown in Figure 2 were established.

TERM	DEFINITION
HUMAN ROLE	TASK IS PERFORMED COMPLETELY BY HUMANS OR BY HUMANS WITH HAND-HELD TOOLS BETWEEN THEM AND TASK OBJECT (IVA AND EVA)
HUMAN SUPPORTED BY MACHINES	TASK IS PERFORMED BY HUMANS WITH MANUALLY OPERATED OR PROGRAMMABLE MACHINES, ONE COMPLEMENTING THE OTHER (IVA AND EVA). THIS INCLUDES RMS, INTERACTIVE COMPUTERS, ETC.
MACHINES	TASKS PERFORMED EXCLUSIVELY BY COMPUTERS, TELEOPERATORS, AUTOMATA, ROBOTS (WITH HUMAN SUPERVISION.)

Figure 2. Definitions.

The selected projects analyzed in this study were limited to Earth-orbital projects that were considered sufficiently representative to provide valid results for a broad spectrum of orbital missions.

V. QUALITATIVE ASSESSMENT

The qualitative assessment was performed as shown in Figure 3. The projects selected for further study were:

1) Space Platforms (manned and unmanned)
2) Geosynchronous Platform
3) Free-Flying Spacecraft (Space Telescope, etc.)
4) Power Systems
5) Large Space Structures
6) Life Sciences
7) Solar Terrestrial Science
8) Materials Processing In Space (MPS).

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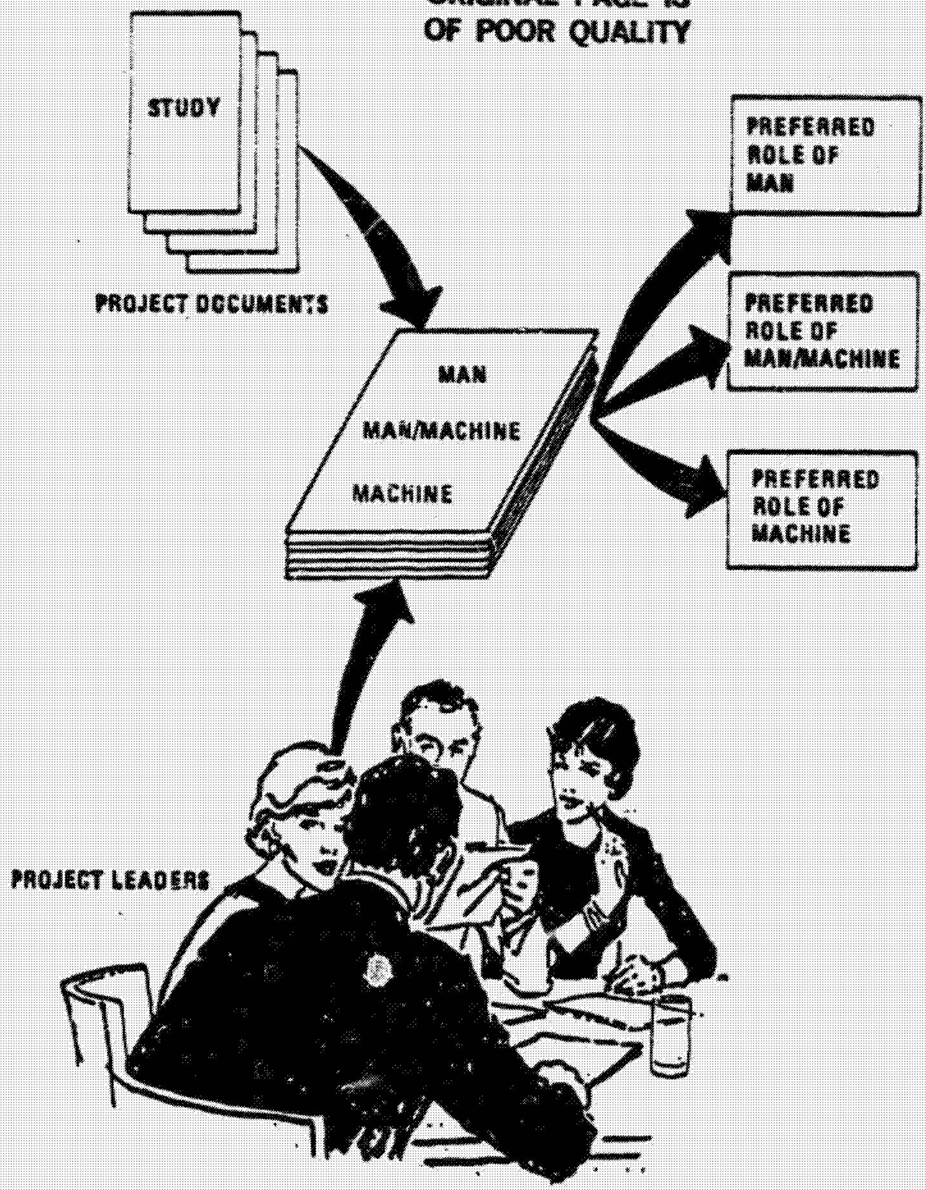

Figure 3. Qualitative assessment.

A. Preferred Human Roles

Some of the projects above were under active study; others were in between studies, but results were documented. Therefore, data were collected from conversations with cognizant project personnel and from project documentation. Raw data were recorded on worksheets. These worksheets were the basis of task categorization into tasks for humans, human/machine, and for machines alone. A sample sheet is shown in Figure 4 concerning the Science and Applications Space Platform.

From these worksheets, manned activities were extracted and displayed in a matrix. Human tasks were divided into normal scheduled activities, unscheduled activities, and contingency activities.

PROJECT NAME: SASP

CONTACT: J. SCHWARTZ, W. RAMAGE DATE: 5/9/80

REFERENCE DOCUMENTS: 1. "Payloads Requirements/Accommodations Assessment Study for SASP" First Quarterly Review TRW 3/19/80
2. "Mid-Term Briefing - Conceptual Design Study - SASP" MDAC 3/80
3. "SASP Study Report" PD Phase A Report 4/79

MARSHALL SPACE FLT. CTR.
S. HALL, PD24
G. JOHNSON, PD34

TASK
MAN ONLY
FILM REPLACEMENT
INSTRUMENT/EQUIPMENT EXCHANGE
SCHEDULED C/O, MAINTENANCE
NON-SCHEDULED MAINTENANCE
DEPLOYMENT ASSEMBLY SUPPORT
FOCAL PLANE INSTRUMENT EXCHANGE
SUBSYSTEM EQUIPMENT EXCHANGE
EXP. CAL/ALIGNMENT
CONTINGENCY
MAN/MACHINE
PAYLOAD DEPLOYMENT/RETRIEVAL/EXCHANGE
OBSERVATION/INSPECTION OF EXPERIMENTS
CONTINGENCY
PLATFORM ACTIVATION
- BERTH ORB TO PS (USING RMS)
- REMOVE SASP FROM ORB & BERTH TO PS
- RELOCATE OR STOW RMS
- DEPLOY TELEFOLD SECTION
- SUBSYSTEM C/O, RELEASE PS/SASP
TANK REPLACEMENT
GAS/CRYO REPLACEMENT
MACHINE ONLY
ORBIT REBOOST
INSPECTION

Figure 4. Sample worksheet.

The significance of man's role in unscheduled and contingency tasks was amply demonstrated by Skylab Extra Vehicular Activity (EVA). Premission plans called for 29 man-hours of scheduled EVA spread over 6 EVA periods. During those periods, various experiment materials were to be retrieved. As Skylab progressed, experience and confidence in EVA capabilities grew. Numerous unscheduled EVA experiments operations, repairs, and servicing tasks were added. At the conclusion of Skylab 82.5 man-hours of EVA, nearly triple what was planned, were chalked up in 10 EVA periods (Fig. 5). The most dramatic added tasks were the repairs that brought the launch damaged Skylab vehicle to operational status only 2? days after the damage occurred. Without them, the $2.6 billion program would have been in jeopardy of failing.

The preferred human roles based on his unique attributes as derived from the task matrix are:

1) Rapid response to unforeseen emergencies

2) Self contained operation in absence of ground communications

3) Rapid sensing, reaction, and vehicle control

4) Enhancement of instrument flexibility

5) Simplification of complex systems

6) Backup reliability

7) Equipment repair and improvisation

8) Investigation and exploration

9) Availability.

B. Categorization of Functions Best Performed by Humans, Human/Machine, and Machines Only

Using the same matrix data base, the task categories and their assignments to humans, human/machine, and machines only were extracted and are shown in Figures 6 and 7.

The projects reviewed and the study of actual precedents evolved a set of criteria that can be used to assign functions to humans, human/machine, and to machines (e.g., teleoperator). They are shown in Figure 8.

It is interesting to note that, depending on the type of projects, their scheduling in location and time, there are cou[illegible]-current trends in the use of humans versus machines. A few examples are s[illegible] in Figure 9. Some missions begin automated and finally will be manned with some automation involved. Other missions will start off manned and will become automated later on with some manned activity involved.

Figure 10 summarizes typical space activities and their assignment to humans, human/machine, and to machines only. The main reason for this situation is that initially automated mission modes were employed where high risk environments were to be

EXAMPLE: EVA BY SKYLAB CREW

- SCHEDULED EVA - 29 MAN-HOURS (6 EVA PERIODS)
  - ATM FILM RETRIEVAL
  - DO 24 SAMPLE RETRIEVAL
  - S230 COLLECTOR RETRIEVAL
- UNSCHEDULED EVA - 53.5 MAN-HOURS (10 EVA PERIODS)
  - DEPLOY OWS SOLAR ARRAY
  - DEPLOY TWIN-POLE THERMAL SHIELD
  - INSTALL RATE GYRO CABLE
  - REPAIR CHARGER BATTERY REGULATOR MODULE (CBRM)
  - REPAIR S193 ANTENNA
  - REPLACE S082A FILM MAGAZINE
  - SECURE S054 AND S082A APERTURE DOOR OPEN
  - REPAIR S054 FILTER WHEEL
  - CLEAN S052 OCCULTING DISC
  - INSTALL AND RETRIEVE SAMPLES
  - INSTALL AND RETRIEVE S149 EXPERIMENT
  - INSTALL, OPERATE, AND RETRIEVE T025, S020, AND S201 EXPERIMENTS
  - REMOVE S055, S056, AND S082A RAMP LATCHES
  - OBTAIN TEMPERATURE OF S020 EXPERIMENT
- 18 EXTRA MISSION OBJECTIVES
- 13 IN-FLIGHT REPAIR TASKS

Figure 5. Significance of unscheduled task occurrence.

MAN/MACHINE

TASK \ PROJECT	SASP	GEO PLATFORM	SPACE TELESCOPE	POWER SYSTEMS	LARGE SPACE STRUCT	LIFE SCIENCES	MPS
DEPLOY PAYLOADS/SPACECRAFT	✓	✓	✓	✓	✓	✓	✓
RENDEZVOUS	✓	✓	✓	✓	✓	✓	✓
DOCKING/BERTHING	✓	✓	✓	✓	✓	✓	✓
CAPTURE W/RMS	✓		✓	✓		✓	✓
INST ORB REPL UNITS	✓	✓	✓	✓	✓	✓	✓
INSP & MAINTENANCE	✓	✓	✓	✓	✓	✓	✓
EXPENDABLE REPLENISH	✓	✓	✓	✓	✓	✓	✓
EVA REPAIR	✓	✓	✓	✓	✓	✓	✓
ASSEMBLY	✓	✓			✓		✓
CHECKOUT	✓	✓	✓	✓	✓	✓	✓

MACHINE ONLY

TASK	SASP	GEO PLATFORM	SPACE TELESCOPE	POWER SYSTEMS	LARGE SPACE STRUCT	LIFE SCIENCES	MPS
ORBIT REBOOST	✓	✓	✓		✓	✓	✓
ORBIT TRANSFER		✓			✓		
INSPECTION	✓	✓	✓	✓	✓	✓	✓
REMOTE REPAIR	✓	✓	✓	✓	✓	✓	✓
REMOTE REPLACEMENT	✓	✓	✓	✓	✓	✓	✓
HAZARDOUS OPERATIONS	✓	✓	✓	✓	✓	✓	✓
ASSEMBLY		✓			✓		

Figure 6. Major tasks performed.

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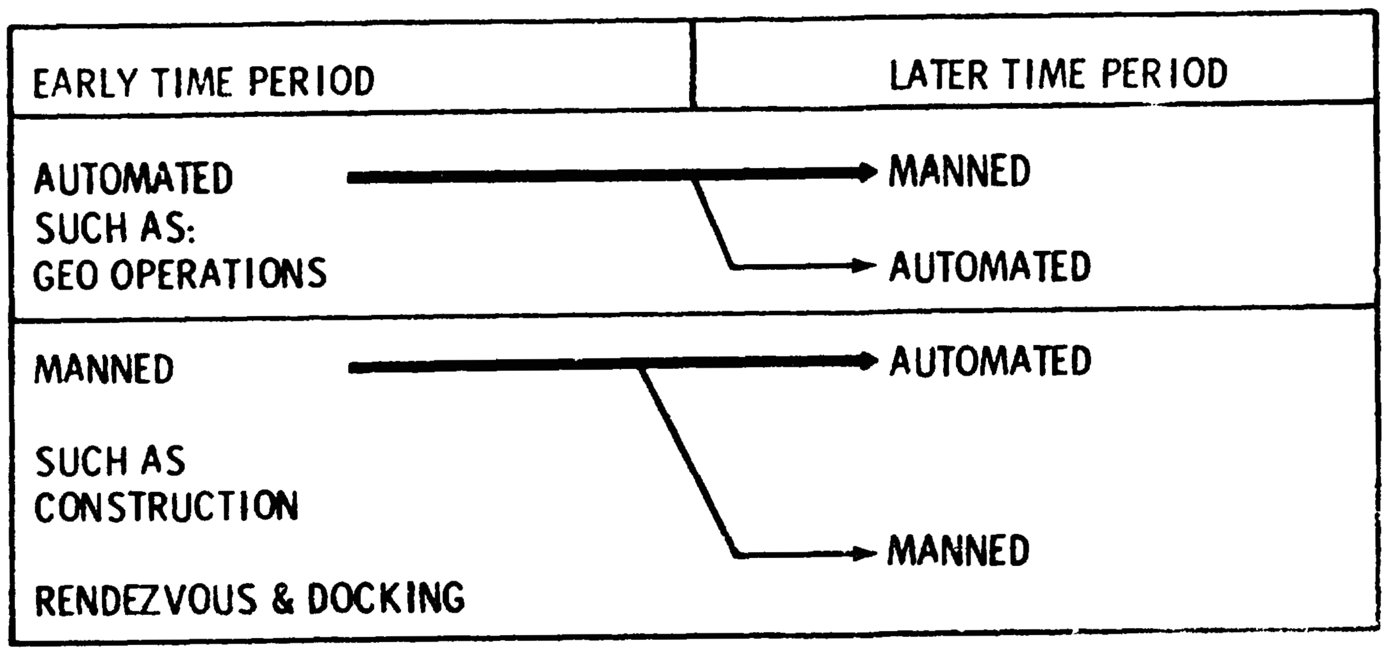
TASK \ PROJECT	SASP	SEG PLATFORM	SPACE TELESCOPE	POWER SYSTEMS	LARGE SPACE STRUCT	LIFE SCIENCES	MPS
NORMAL ACTIVITIES/OPERATION							
REPLACE SPARES	✓		✓	✓	✓	✓	✓
REPLACE EXPENDABLES						✓	✓
EQT CALIBRATION						✓	✓
EXP MONITOR/SUPERVISION	✓				✓	✓	✓
ASSEMBLY	✓	✓	✓	✓	✓	✓	✓
DATA INTERPRETATION						✓	✓
SPECIMEN HANDLING						✓	✓
ROUTINE C/O, SERVICE	✓	✓	✓	✓	✓	✓	✓
[illegible]TIVITIES							
TROUBLE SHOOT	✓	✓	✓	✓	✓	✓	✓
REPAIR	✓	✓	✓	✓	✓	✓	✓
MODIFY PROTOCOL	✓	✓		✓	✓	✓	✓
RESOURCE ALLOCATION	✓	✓		✓	✓	✓	✓
WORKAROUND SOLUTIONS	✓	✓		✓	✓	✓	✓
DEPLOY, RETRACT, JETTISON APPENDAGES	✓	✓	✓	✓		✓	

Figure 7. Major tasks performed by man.

ORGANIZATION		NAME
PD-24	MARSHALL SPACE FLIGHT CENTER	S. HALL
		DATE: JUNE '80

1. FREQUENCY
   - A. SCHEDULED (ν OF TASK)
   - B. UNSCHEDULED (TASK INITIATING EVENT)
   - C. CONTINGENCY (NATURE OF CONTINGENCY)
   - D. OTHER
2. TASK DURATION
3. REPETITIVENESS
   - A. REPETITIONS (TOTAL NO.)
   - B. BASIS
4. COMPLEXITY
   - A. SUBTASKS
   - B. ALTERNATIVE OPTIONS
5. TASK CRITICALITY
   - A. LIFE
   - B. MISSION
   - C. VEHICLE
   - D. ENGINEERING DATA
   - E. SCIENTIFIC DATA
6. RESPONSE TIME
   - A. PERIOD
   - B. KEY EVENT
7. TASK CONSTRAINTS
   - A. LOCATION
   - B. COMMUNICATIONS
   - C. LIGHTING
   - D. "WINDOWS"
   - E. OTHER
8. TASK HAZARDS
   - A. THERMAL
   - B. RADIATION
   - C. EMI
   - D. DANGEROUS MATERIALS
   - E. HIGH PRESSURES
   - F. ELECTRICAL
   - G. LIMITED ACCESS
9. SIMILARITY TO OTHER TASKS
10. FLEXIBILITY OF TASK
11. AUTONOMY
12. AVAILABILITY
   - A. NEW CAPABILITY
   - B. EXISTING CAPABILITY
   - C. PRECEDENT

Figure 8. Criteria to assign functions to man, man/machine, or machine (teleoperator).



THE ROLE OF MAN IN SPACE IS HIGHLY VARIABLE WITH TIME AND LOCATION

Figure 9. General trends.

MAN

NORMAL ACTIVITIES/OPERATION
REPLACE SPARES
REPLACE EXPENDABLES
EQT CALIBRATION
EXP MONITOR/SUPERVISION
DATA INTERPRETATION
SPECIMEN HANDLING
ROUTINE C/O, SERVICE
ASSEMBLY
CONTINGENCY ACTIVITIES
TROUBLE SHOOT
REPAIR
MODIFY PROTOCOL
RESOURCE ALLOCATION
WORK AROUND SOLUTIONS
DEPLOY, RETRACT,
JETTISON APPENDAGES

MAN/MACHINE

DEPLOY PAYLOADS/SPACECRAFT
RENDEZVOUS
DOCKING/BERTHING
CAPTURE W/RMS
INST ORB REPL UNITS
INSP & MAINTENANCE
EXPENDABLE REPLENISH
EVA REPAIR
ASSEMBLY
CHECKOUT

MACHINE

ORBIT REBOOST
ORBIT TRANSFER
INSPECTION
REMOTE REPAIR
REMOTE REPLACEMENT
HAZARDOUS OPERATIONS
ASSEMBLY

Figure 10. Summary of task categorization.

explored and, therefore, the high cost of equivalent manned missions would be prohibitive. After the environment is sufficiently known, appropriate manned spacecraft can then be designed for minimum cost and risk including automation in support of human activities. In contrast, initially manned missions are considered to explore technical and scientific methods and procedures in the space environment. After sufficient knowledge and experience has been accumulated, much of this can then be automated later leaving special, supervisory tasks to humans.

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VI. QUANTITATIVE ASSESSMENT

This section covers the selected mission modeling and the extraction of projected requirements for the support of human presence in space. A schematic overview of this part is given in Figure 11.

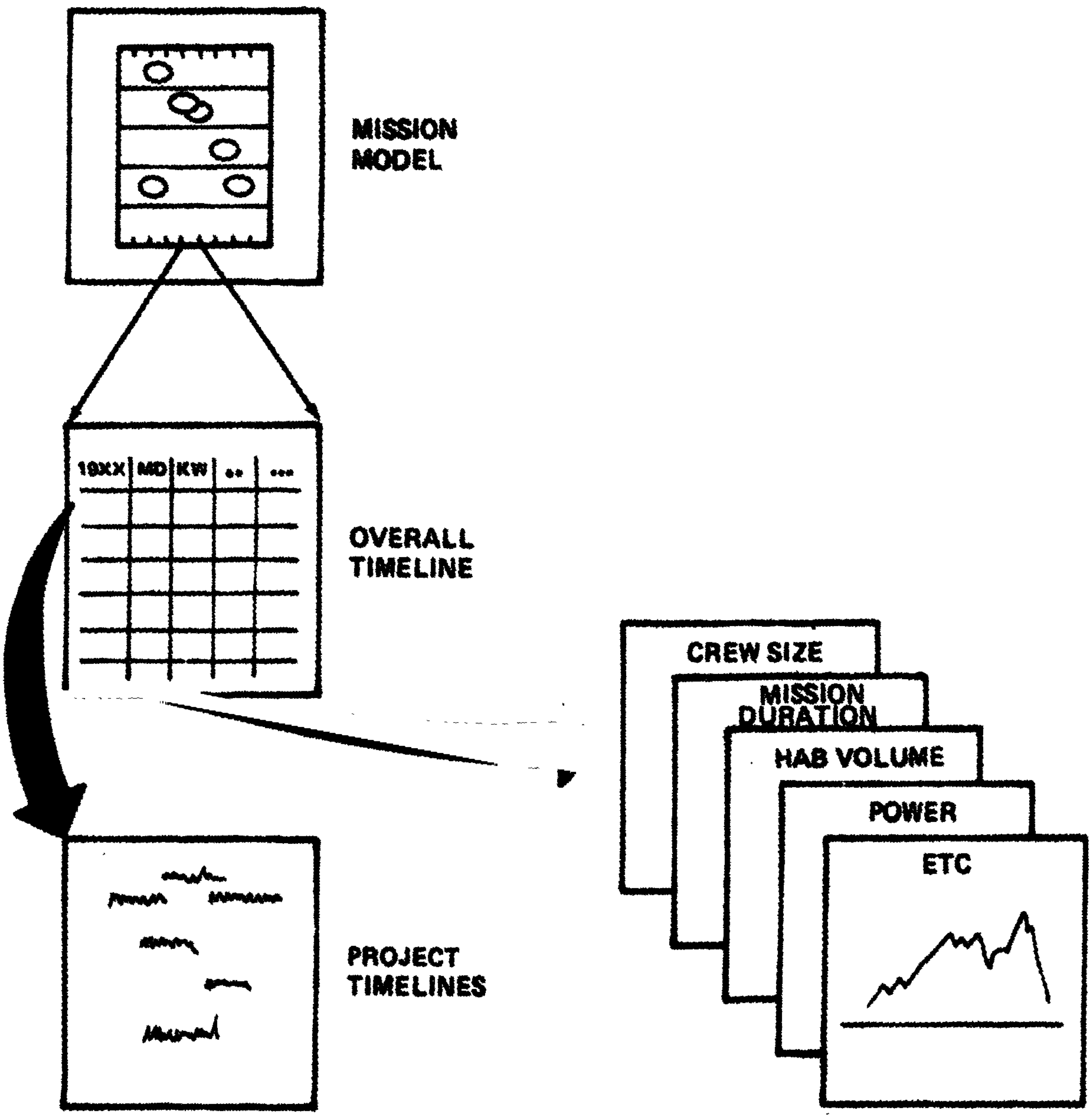


Figure 11. Quantitative assessment.

A. Mission Model

Any mission model will have to assume a number of guidelines. The ones listed in Figure 12 are considered reasonable and the best that can be obtained at this time.

From the data base described initially in this study a mission model was constructed. The abbreviations used for the Free-Flyers are shown in the following:

ST	Space Telescope
GP-B	Gravity Probe B
AXAF	Advanced X-Ray Astrophysics Facility
POF	Pinhole/Occulter Facility
STIFT	Shuttle Time and Frequency Transfer Experiment
SGG	Supercooled Gravity Gradiometer
LAMAR	Large Area Modular Array of Reflectors
VLBI	Very Long Baseline Interferometer
OST	Orbiting Submillimeter Telescope
TAT	Thinner Aperture Telescope
GWI	Gravity Wave Interferometer
COSMIC	Coherent Optical System of Modular Imaging Opportunity
VLST	Very Large Space Telescope
SCD	Solar Cycle and Dynamics Mission
LADIT	Large Ambient IR Telescope

The mission model itself is shown in Figures 13 and 14. The following is to be noted with regard to this model:

1) Only the initial flight dates of a particular spacecraft or payload are shown

2) Each project can require several types of missions during a given year (delivery, revisit, reboost, etc.)

3) Different types of missions may impose different requirements (crew size, duration, etc.)

4) Optimization of the mission model was not attempted because of limited resources.

B. Timelines

Figure 15 shows a detailed sample of a set of individual mission timelines. These were assembled and summarized into overall annual timelines. A typical page from an overall timeline part is given in Figure 16 for the year 1991. Each project is divided into missions of various types required for that project. From these missions, specific requirements are determined in terms of crew size, mission duration, power, and spacecraft volume.

GENERAL:	• EARLY SORTIE MISSION, LUNAR, PLANETARY, GEO DEBRIS REMOVAL AND DOD MISSIONS EXCLUDED
	• FLIGHT CREW INCLUDED IN MAN DAY TOTALS
PLATFORMS:	• INSTRUMENT EXCHANGE SORTIES QUARTERLY FOR PUP AND GEO
	• ADVANCED PUP REQUIRES 2.0 TIMES THE MAN DAYS OF PREDESCESSORS
	• ANNUAL PUP REBOOST MODULE SERVICING
	• POWER UTILIZATION PLATFORM MAINTENANCE EVERY 2.5 YEARS
	• GEO SERVICING AT 3 YEAR INTERVALS (AUTOMATED/MANNED)
FREE FLYERS:	• INITIAL DEPLOYMENT & C/O
	• MAINTENANCE, RETRIEVAL AND RELAUNCH MISSIONS
POWER SYSTEMS:	• DEPLOYMENT/CONSTRUCTION AND C/O SHOWN FOR DEVELOPMENT UNIT.
	• OPERATIONAL MAN DAYS (INCLUDING MAINTENANCE) ARE PART OF THE USER MISSIONS
OTV:	• RETURNED TO GROUND AFTER EACH MISSION
CONSTRUCTION:	• PERFORMED INTERMITTENTLY ON ADVANCED PUP.

Figure 12. Mission model guidelines.

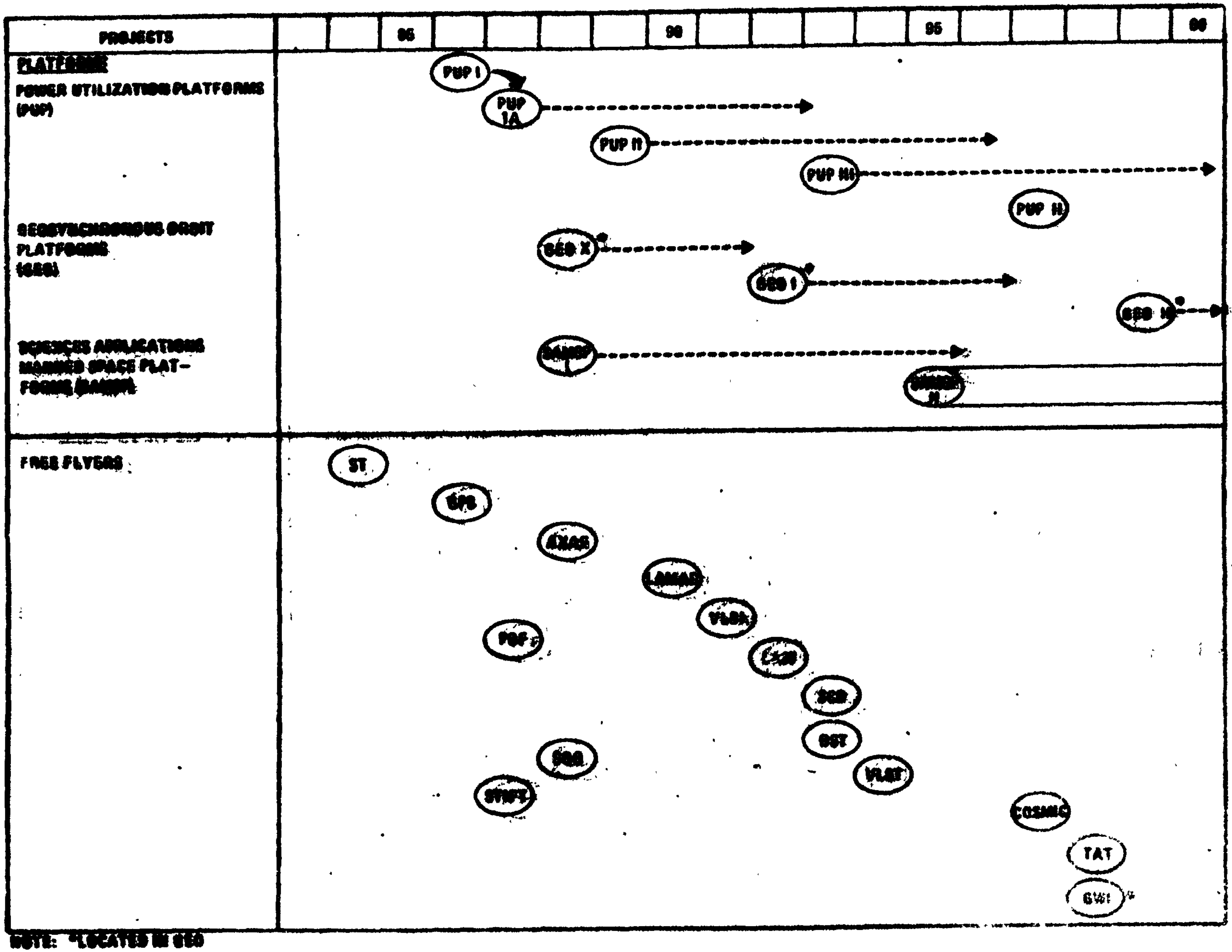
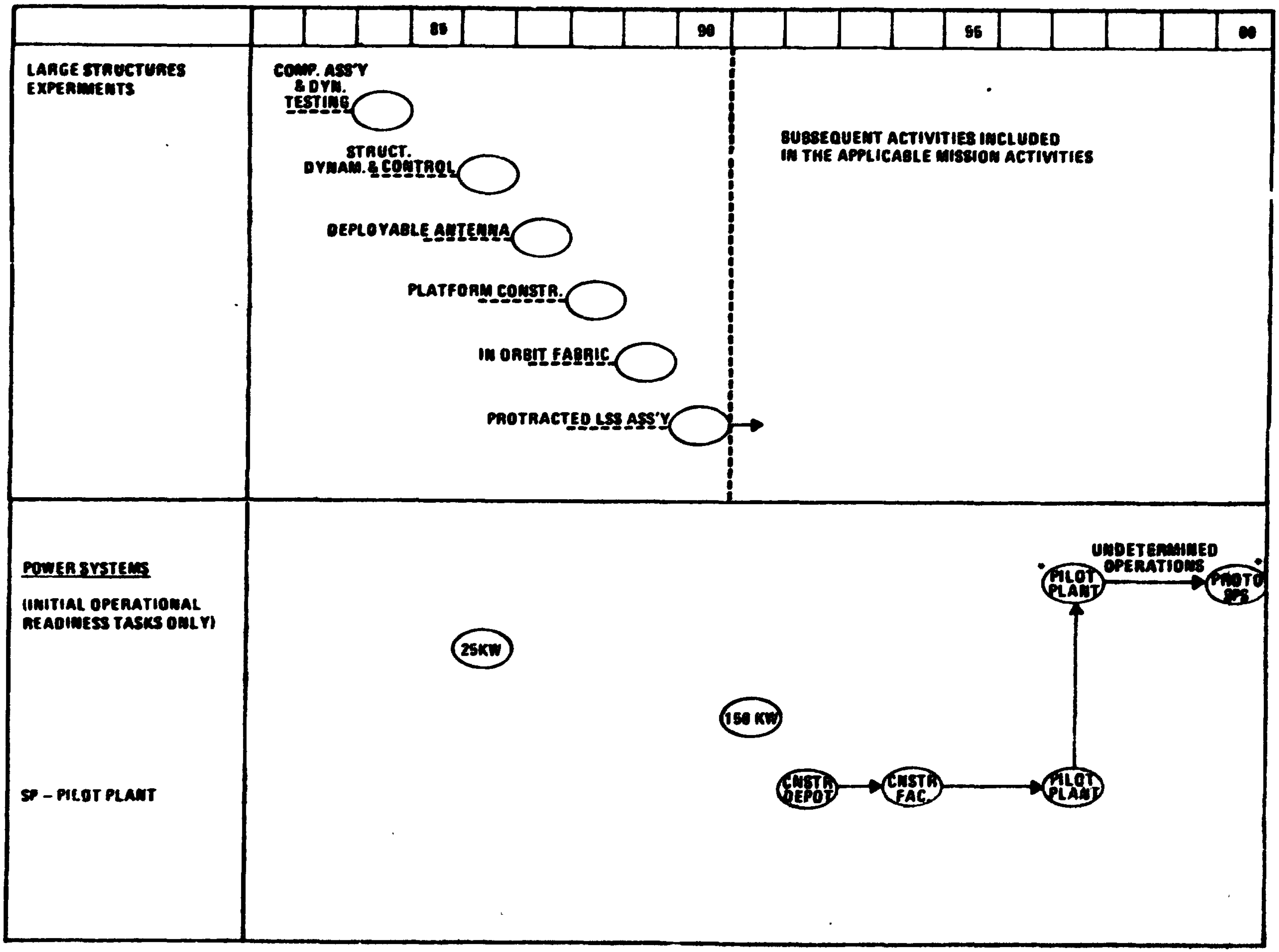


Figure 13 Summary of mission model (I).



NOTE: *LOCATED IN GEO

Figure 14. Summary of mission model (II).

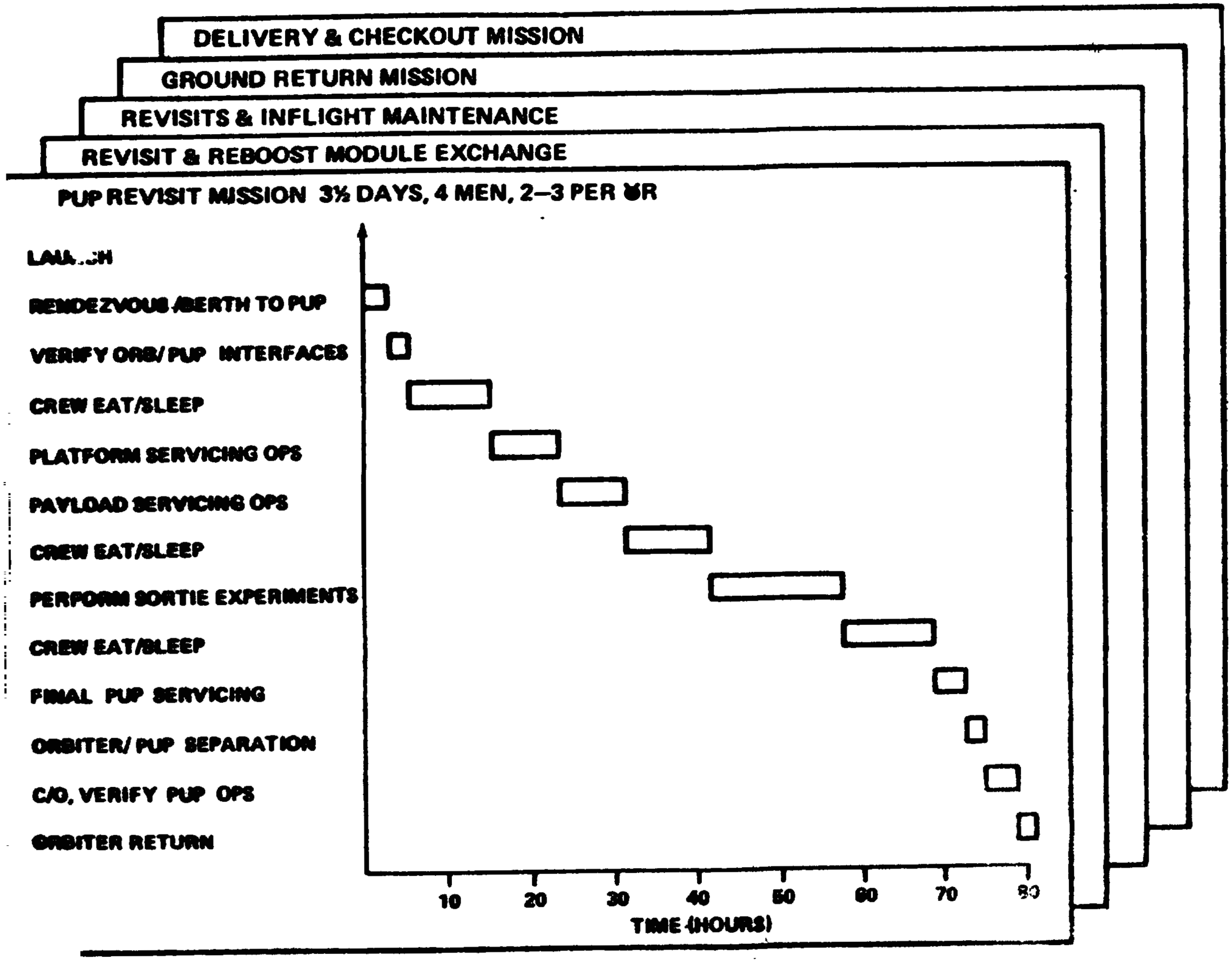


Figure 15. Project level mission timelines.

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YEAR PROJECT MISSION	MISSION TYPE/PHASE	CREW SIZE	MISSION DURATION DAYS	MAN DAYS	HABITATION POWER PROJECTION	SPACECRAFT VOLUME (NON-SORTIE MISSIONS)
1991						
PUP 1A						
MISSION A	REVISIT	4	3½	14	N/A	–
MISSION B	REVISIT	4	3½	14		
MISSION C	REVISIT	4	3½	14		
MISSION D	GROUND	4	3½	10		
MISSION E	RETURN	4	3	10		
				62		–
PUP 2						–
MISSION A	REVISIT	4				
MISSION B	REVISIT					
MISSION C						
SAMSP						
MISSION A	DELIVERY, LS RESEARCH, & MP RESEARCH	3 2 2	4 90 90	12 180 180	– 6.4 KW	– 4.5 KCF
MISSION B	DELIVERY, LS RESEARCH & MP RESEARCH	3 2 2	4 90 90	12 180 180	– 6.4 KW	– 4.5 KCF
MISSION C	DELIVERY, LS RESEARCH & MP RESEARCH	3 2 2	4 90 90	12 180 180	– 6.4 KW	– 4.5 KCF
MISSION D	DELIVERY, LS RESEARCH & MP RESEARCH	3 2 2	4 90 90	12 180 180	– 6.4 KW	– 4.5 KCF
SUBTOTAL				1488		
PAGE SUMMARY			NON SORTIE MAN DAYS SORTIE MAN DAYS TOTAL MAN DAYS	1488 211 1699	MAXIMUM HAB. PWR. RQMT.: 6.4 KW	MAX. PRESSURIZED SPACECRAFT VOLUME: 4.5 KCF

Figure 16. Overall timeline (typical page).

Summing up all individual project/mission timelines provided the composite chart, Figure 17. At the bottom the separate totals for sortie and non-sortie missions are shown as the grand total per year. It should be noted that several early sortie missions were excluded, since their requirements would not affect the outcome of the study.

C. Requirements

Requirements derived from the previously described mission model are summarized in Figure 18. The man-days needed each year to satisfy sortie and non-sortie mission requirements are shown on the upper half of the figure. In sortie missions, the approximate number of Shuttle flights needed are shown on the vertical scale assuming each Shuttle flight yields 20 man-days. For non-sortie mission, the equivalent crew size is shown on the vertical scale. This is the size of crew required to satisfy non-sortie man-day requirements assuming (1) continuous presence of a crew on-orbit and (2) consolidation of non-sortie mission activities in one location. Thus, 365 man-days were equated to 1 crew man for 1 year. The use of approximate Shuttle flights and equivalent crew size are for rough comparisons only.

The breakdown of man-days by role is summarized on the lower half of Figure 18. The roles used were: inflight maintenance (scheduled), payload retrieval, payload delivery, assembly and construction, and in-situ experimentation. Nearly all in-situ experimentation is done in the mission model on non-sortie missions. Notice that man-day projections for non-sortie missions are about five times that for sortie missions, and man-days for experimentation are about five times that for other roles. The envelope of man-day projection for non-experimentation roles was taken from the lower-left and superimposed on the lower-right to emphasize this difference.

Additional projections of mission model requirements are shown in Figure 18. The non-sortie man-day requirements are satisfied by long duration missions conducted from manned platforms. The maximum pressurized volume of modules required at such platforms is shown in the upper left. The volume (in cubic feet) for the Shuttle cabin, cabin and long Spacelab module, unpressurized Shuttle cargo bay, and Skylab is shown for comparison. The right-hand scale shows how projected volume requirements compare to Spacelab long modules and platform crew size. Projected requirements would be higher in the late 1990's if there were only one manned platform instead of two.

The maximum crew size for sortie and non-sortie missions is shown in the lower left. Sortie mission crews exceed the present Shuttle baseline in the late 1990's because of anticipated SPS activities.

The capacity of power systems expected to be available in the next two decades are shown at the upper right. They easily satisfy habitation system power requirements during that era.

Projected staytimes for crews are shown at the lower right. Early Shuttle missions are constrained to about 7 days. The advent of large power systems stretches that to about 30 days for sortie missions and 90 days or more for non-sortie missions.

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PROJECT YEAR	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
PUP 1	0	0	0	62	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PUP 1A	0	0	0	0	60	60	63	60	62	60	60	63	60	62	60	60	63	60
PUP 2	0	0	0	0	0	0	60	60	63	60	62	60	60	63	60	62	60	60
PUP 1'	0	0	0	0	0	0	0	0	0	0	120	120	126	120	124	120	120	126
GEO X	0	0	0	0	0	28	0	0	0	28	0	0	0	28	0	0	0	28
GEO 1	0	0	0	0	0	0	0	0	0	28	0	0	0	28	0	0	0	28
GEO 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28
SAMSP 1	0	0	0	0	0	264	1488	1488	1488	1488	1488	1488	1488	2208	2208	2208	2208	2208
SAMSP 2	0	0	0	0	0	0	0	0	0	0	0	0	264	1488	1488	1488	1488	1488
SUBTOT	0	0	0	62	60	352	1611	1608	1613	1644	1730	1731	1998	3997	3940	3938	3939	4026
FREE FLIERS																		
ST	0	16	0	12	0	16	0	16	0	12	0	16	0	16	0	12	0	16
GPB	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STIFT	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
POF	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0
AKAF	0	0	0	0	0	16	0	0	12	0	0	16	0	16	0	0	12	0
SGO	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0
LAMAR	0	0	0	0	0	0	0	20	0	0	12	0	0	20	0	20	0	0
VLBI	0	0	0	0	0	0	0	0	16	0	0	12	0	0	16	0	16	0
LAIT	0	0	0	0	0	0	0	0	0	16	0	0	12	0	0	16	0	16
SEO	0	0	0	0	0	0	0	0	0	0	16	0	0	12	0	0	16	0
UST	0	0	0	0	0	0	0	0	0	0	16	0	0	12	0	0	16	0
VLST	0	0	0	0	0	0	0	0	0	0	0	80	0	0	12	0	0	12
COSMIC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	180	0	0	12
TA?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	180	0
GVI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	80	0
SUBTOT	0	16	0	44	16	48	0	36	28	28	44	124	12	76	208	48	320	56
LARGE SPACE STRUCTURES																		
A&D TST	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G&C TST	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DEP ANT	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0
FLT CON	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0
ORB FAB	0	0	0	0		0	26	0	0	0	0	0	0	0	0	0	0	0
PR CNST	0	2	0	20	20	20	26	60	0	0	0	0	0	0	0	0	0	0
SUB TOT	0	2	0	20	20	20	26	60	0	0	0	0	0	0	0	0	0	0
POWER SYSTEMS																		
25 KW	0	0	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
150 KW	0	0	0	0	0	0	0	0	74	0	0	0	0	0	0	0	0	0
SPS PPL	0	0	0	0	0	0	0	0	0	60	60	260	260	500	500	0	0	0
SPS PTP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	730	1460	1460
SUBTOT	0	0	0	0	0	0	0	0	74	60	60	260	260	500	500	730	1460	1460
SORTIE	0	18	0	144	76	156	148	206	227	264	336	617	508	877	952	290	563	386
NON SORTIE	0	0	0	0	0	264	1488	1488	1488	1488	1488	1488	1752	3696	3696	4426	5156	5156
TOTAL	0	18	0	144	96	420	1636	1694	1715	1742	1824	2105	2260	4573	4648	4716	5719	5542

Figure 17. Projected man-day requirements.

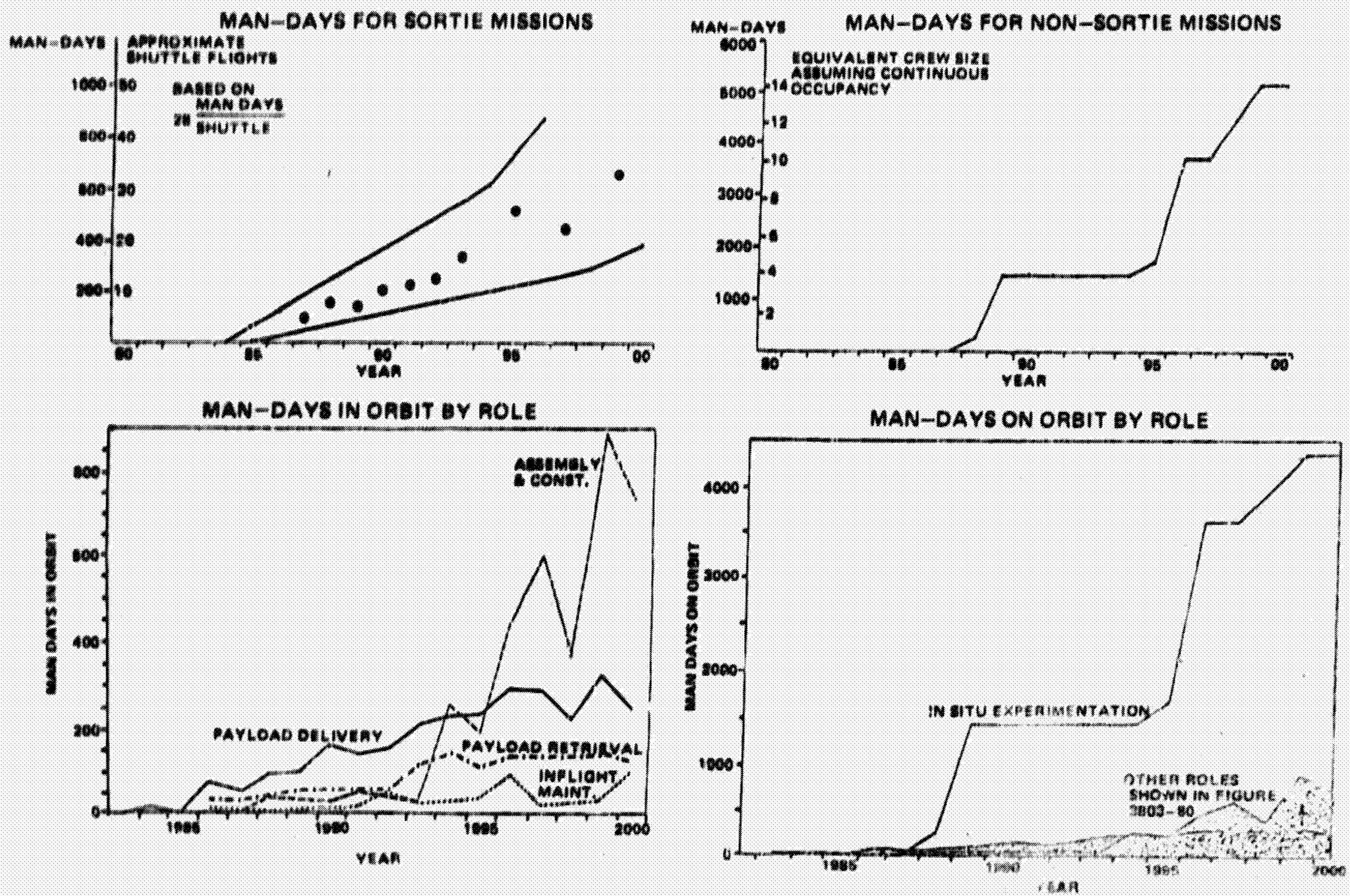

Figure 18. Requirements summary (I).

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D. Response to Requirements by Existing Capabilities

Maximum Pressurized Module Volume Requirements

The maximum pressurized volume required at any one manned platform is plotted year-by-year in Figure 19. This was derived by projecting the crew size for non-sortie missions, calculating the volume required for the crew using Celentano's habitability criteria, adding to that the estimated subsystem volume, and compensating for size and quantity preferences for the manned platforms. The largest manned platform anticipated during the next two decades would consist of two long spacelab modules, launched one at a time, to which a third would eventually be added. After delivery of the first module a crew of two could be supported. The second module ups the capacity to a crew of four. In the mid 1990's, the third module increases the capacity to six at the largest platform. A separate, smaller manned platform is launched about the same time to cover additional volumetric requirements.

Largest Power Systems

Capacity of the largest power systems anticipated over the next two decades are shown on Figure 19. Two trends are noted, one for "operational" systems to extend orbiter staytime, support platforms, etc., and one for solar power system development. The smallest SPS "developmental" unit and the largest "operational" unit are about the same size – approximately 150 kW. Since 1 to 2 kW is required per crewman for a habitat, the "operational" systems expected to be available are quite adequate.

Maximum Crew Size as a Function of Time

The maximum size crew for sortie and non-sortie missions based on the "strawman" mission model is shown in Figure 19. The Shuttle will be operating at its full baseline capacity when exchanging crews at the manned platform in the late 1980's and early 1990's. In the late 1990's its baseline capacity may be met or exceeded depending on how some of the more complex projects are conducted. The maximum crew size for non-sortie (manned platform) missions is four to six through the 1990's.

Estimates of Crew Staytime

During the early to mid-1980's, mission durations are expected to be limited to capabilities of the baseline orbiter. Although closed loop subsystems and orbit based power systems may extend manned missions to a month, additional volume is necessary for longer staytimes. At about the same time the power systems are available, manned platforms will be launched. The manned platforms are essential for studying long term effects of space on man and for laboratory and observatory science disciplines with complex, interactive procedures that are non-routine. For those missions, staytimes of 90 days or more with continuous occupancy are required for efficient operation.

Spacelab Evolutionary Derivatives/Permanent Manned Facilities

Figures 20, 21, and 22 show how an evolutionary platform can be constructed which responds to the manned mission requirements of the strawman mission model.

Figure 20 depicts a multipurpose experiment module attached to the 25 kW power system. In this mode, significant transportation savings result from leaving a complement of laboratory and experiment support hardware on-orbit. The multi-purpose

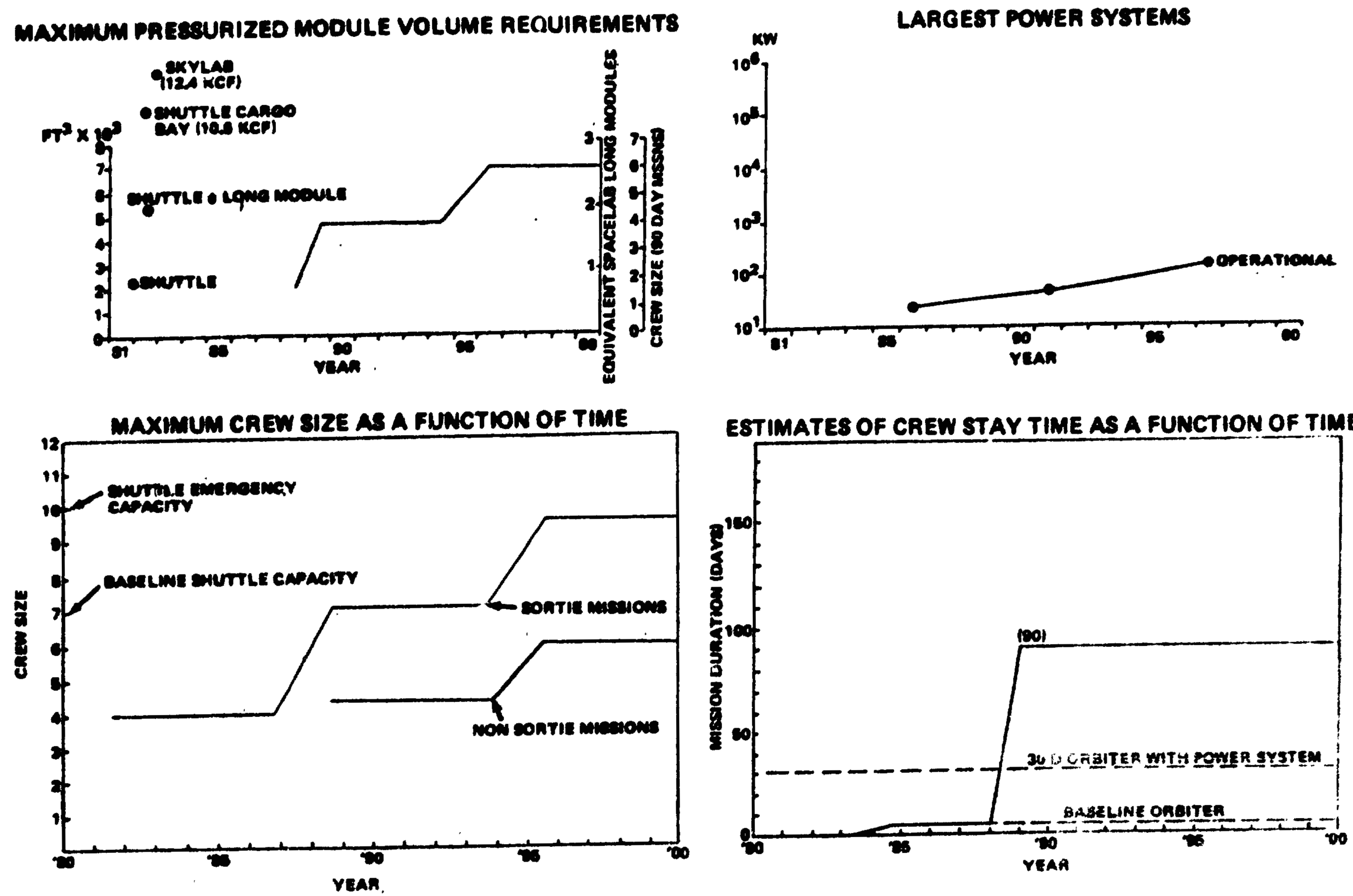

Figure 19. Requirements summary (II).

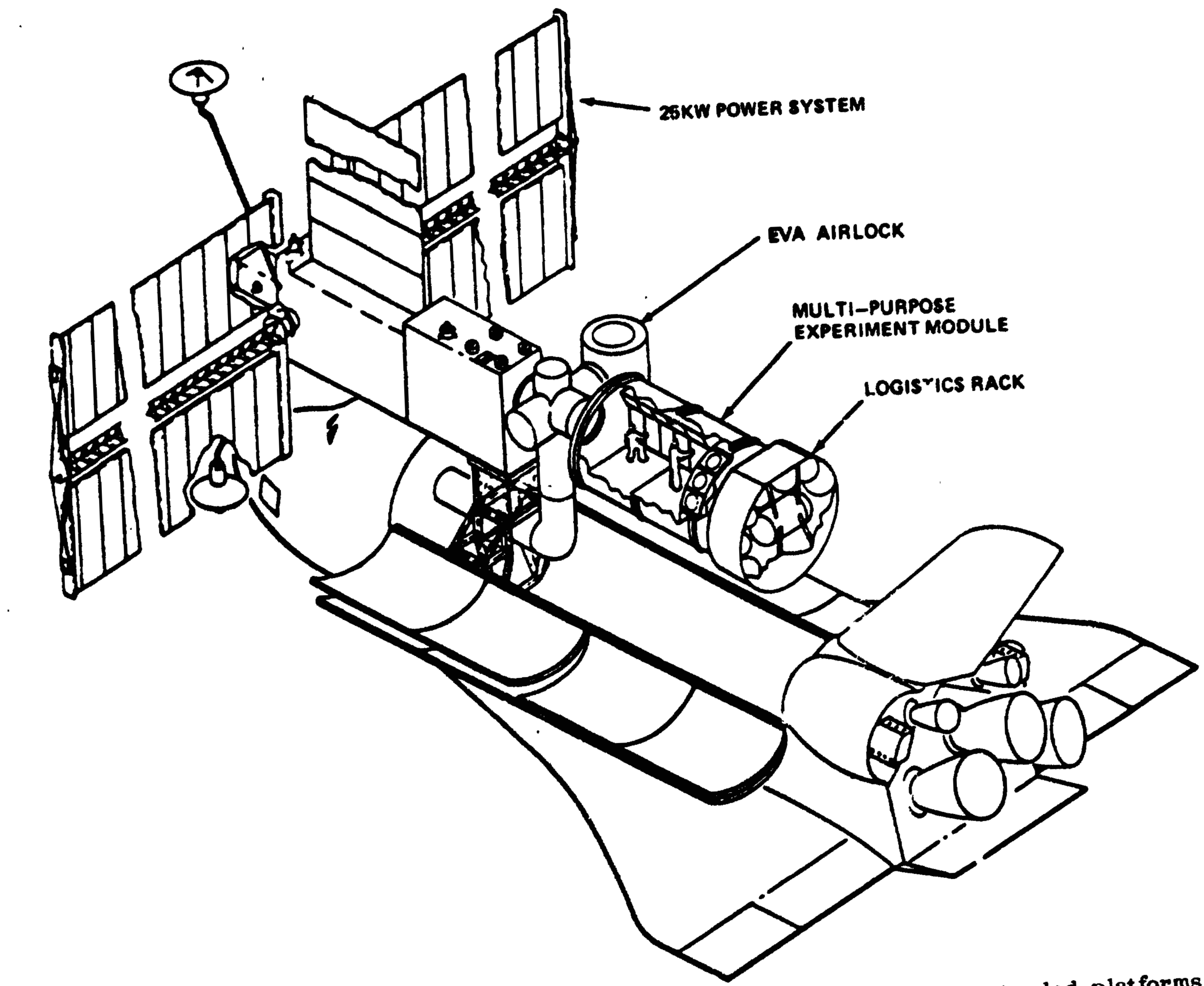

Figure 20. Spacelab evolutionary derivatives for science and applications Shuttle tended platforms.

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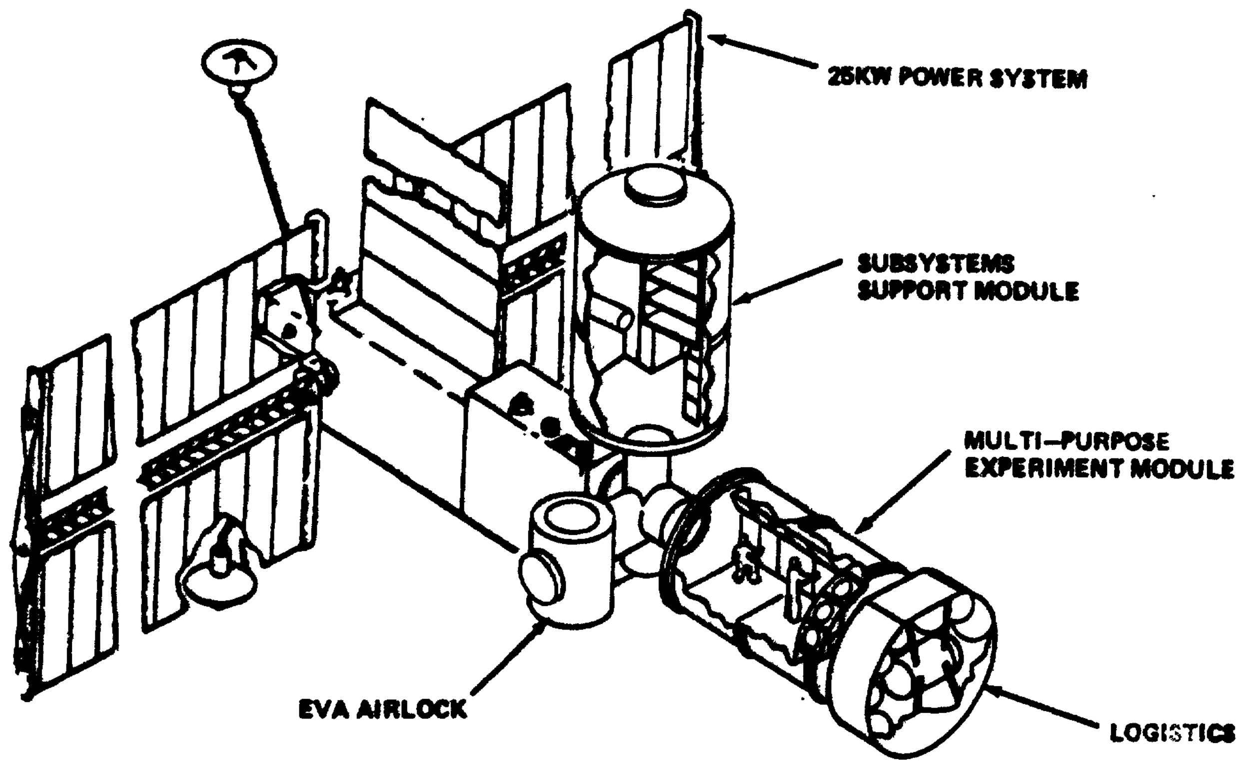

Figure 21. Spacelab evolutionary derivatives for science and applications manned space platforms.

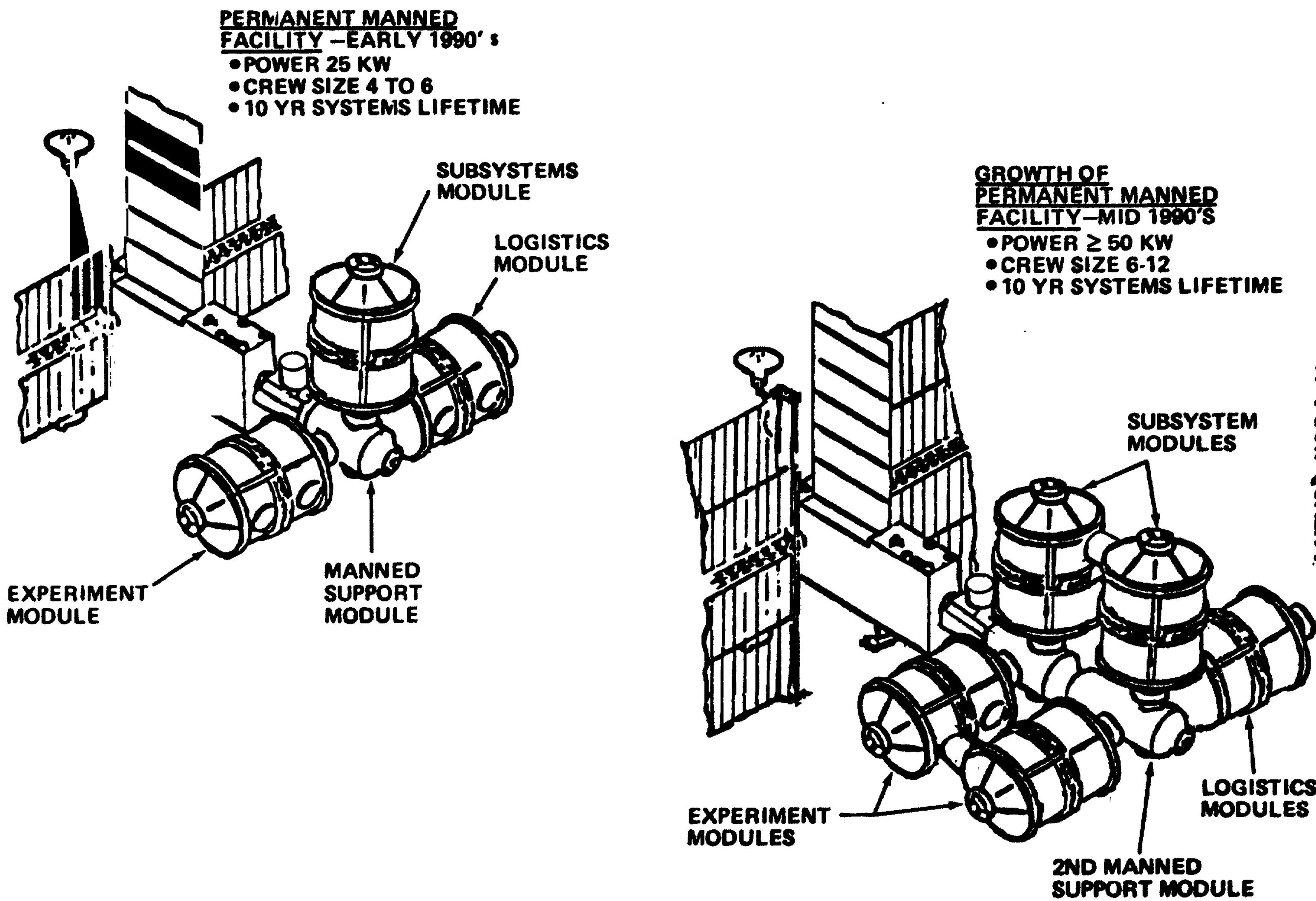

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Figure 22. Permanent manned facilities.

experiment module could be intermittently manned to use the laboratory and to maintain/service equipment. An EVA airlock is provided to guarantee EVA capability during berthed operations.

Figure 21 shows how a subsystems support module may be added to upgrade the previous configuration to a manned free-flying vehicle – independent of the Shuttle except for crew rotation and resupply. In this mode a crew of four may be sustained for up to 90 days. Redundant systems and the capability to launch a Shuttle rescue mission enhance vehicle safety.

Figure 22 indicates how the configuration may be further upgraded to support a crew of six or more and, if appropriate, support dedicated experiment modules. Long system lifetimes are provided by thorough in-flight maintenance. The power systems and logistics carriers are likewise upgraded. The last configuration shows how dual intermodule connections can be provided to further enhance vehicle safety.

VII. SUMMARY

There is a strong role for humans in future space programs. Automated systems will be used to project man's senses and selected capabilities into space, in areas inaccessible to humans with present systems. In many instances they will precede humans. In areas where human functions in space are less demanding and tasks have become routine, automated systems may take over. Where human capabilities are heavily taxed or where automated systems need some in-situ supervision to respond to unexpected emergencies or to exploit unforeseen discoveries, complementary human/automated systems will continue to be used.

A strawman mission model was developed in cooperation with cognizant program personnel. Projections were made of crew size, mission duration, pressurized spacecraft volume, power requirements, etc. Trends of human roles were likewise projected.

Existing capabilities and evolutionary extensions thereof were compared to projected requirements from the strawman model. Capabilities of the Shuttle and the Shuttle/Spacelab combination were effective in satisfying projected requirements until the late 1980's or early 1990's except for long duration manned missions.

A manned platform similar to SAMSP satisfies the unique mission requirements that existing systems cannot. It satisfies those needs without resorting to extensive use of totally new systems. SAMSP would play a supplementary role to the Shuttle freeing it for the heavy delivery/retrieval, maintenance, and sortie traffic anticipated in the 1990's.

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and Gary W. John[illegible]

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William R Marshall
WILLIAM R. MARSHALL
Director, Program Development