THE MINISTRY OF STATE
FOR SCIENCE AND TECHNOLOGY

AN OVERVIEW OF THE
ORBITING ASTROPHYSICS OBSERVATORY STARLAB

DSMA ATCON LTD

ENGINEERS AND ADVANCED TECHNOLOGY CONSULTANTS

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REPORT NO. 815/16/1169

DATE: MAY 19, 1981

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1. PROGRAM EVOLUTION

The STARLAB Concept was initially evolved by NASA Goddard Space Flight Centre as a complement to the Space Telescope (ST) to provide for observations in the ultraviolet spectrum. The ST, with a maximum field of view of approximately 3 arc-min, in conjunction with STARLAB with a field of view of 48 arc-min, would allow the effective exploration of both near and deep space.

As originally conceived, STARLAB would operate in a Shuttle attached mode, as shown in Figure 1, which was postulated as providing a minimum cost program. During the initial four years of the program, NASA sponsored a number of system and subsystem design level studies and ROM costing of the facility. The subsequent phase of the program, aimed at consolidation of the previous studies and the definition of other system constraints, was in the process of being implemented when the program was indefinitely deferred due to budget constraints within NASA.

As a result of the extensive interest of the scientific community in the STARLAB program, the program coordinators began seeking parties who would be interested in pursuing the program. In the same time frame, members of the Canadian Scientific Community had delineated a preliminary concept for a "free-flying" space telescope program. The common interest of the Scientific Communities of Canada, Australia, and the United States in this area, was identified by Canadian industry representatives at a conference held at Tuscon, Arizona, related to telescope development for the 1980's. Exploration of a possible three-nation sponsorship of the STARLAB concept was initiated by Canadian interests. Investigation of this tripartite sponsorship demonstrated the compatibility of this approach from both an industrial and technology standpoint. However, the results of a Canadian cost and industrial participation study conducted in the fall of 1980 highlighted the high costs (dollars/observation hour) for a short duration mission which is a result of the facility operating in a shuttle attached mode.

To alleviate this disadvantage, operation of the facility from a free-flying platform was proposed. NASA, at this time, was in the concept definition phase of such a platform and indicated that the proposed time

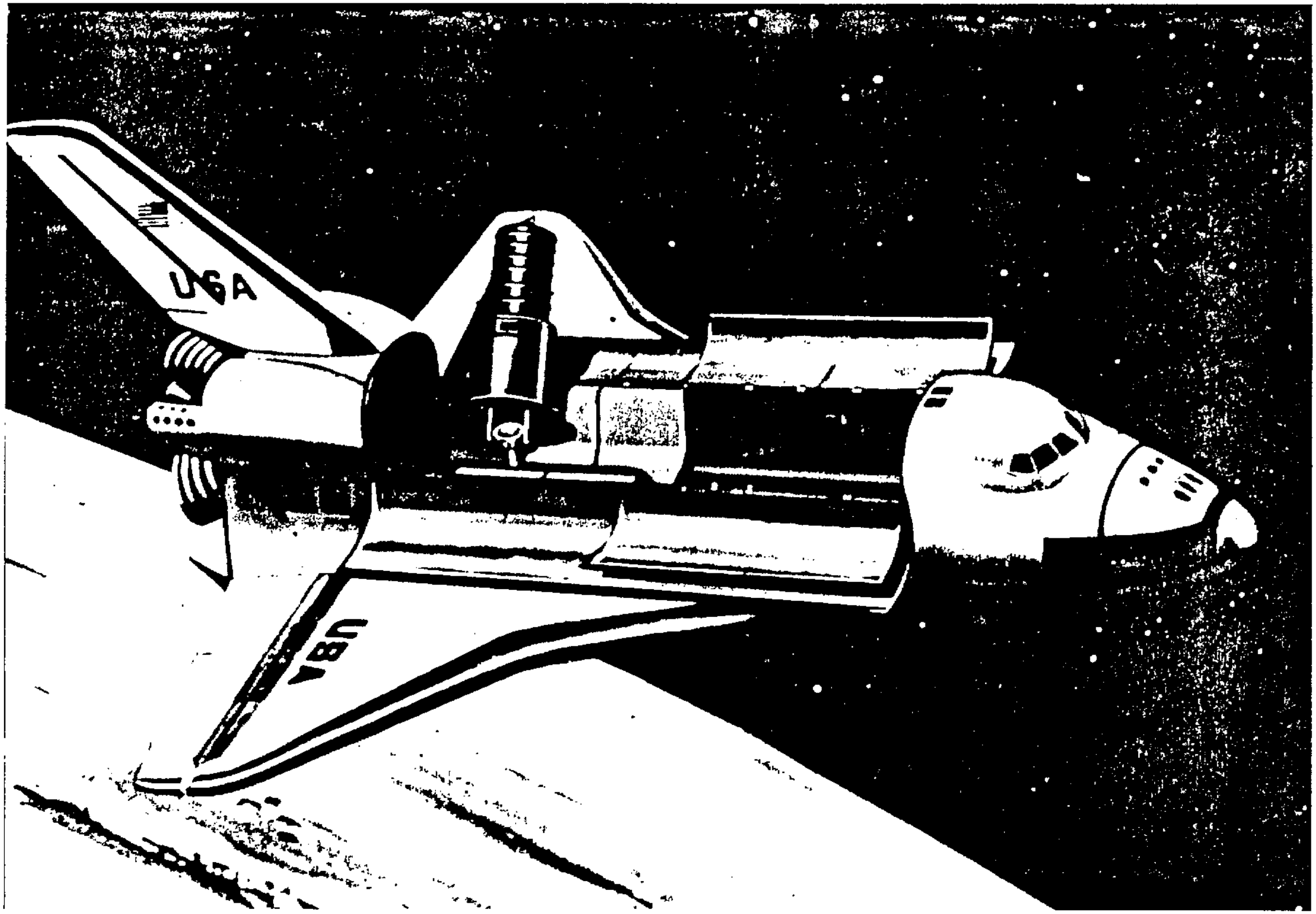


FIGURE 1 - STARLAB IN THE SHUTTLE ATTACHED MODE

frame for this facility was compatible with that proposed for STARLAB. Since the platform program had still to be authorized as a definite budget item and was being held pending the successful first launch of the shuttle, NASA suggested that the STARLAB project should precede through the concept definition phases A and B as a platform attached payload until the end of 1983, at which time they would confirm at what date a platform could be made available for STARLAB.

2. BASIC REQUIREMENTS AND CONFIGURATION STARLAB

It is proposed that STARLAB would be designed to provide the capability to investigate the visual, ultraviolet, and near-infrared properties of extragalactic space and the solar system with both high spatial resolution and wide-angle imaging. The facility will provide scientific flexibility by readily accommodating new instruments as well as rapid and economical reconfiguration to accommodate new experiments.

As configured, STARLAB would utilize a 1-m aperture, f/15 Ritchey-Chretien telescope and accommodate a wide variety of focal plane instruments, with primary emphasis on wide field imaging.

The mission platform utilized by STARLAB will be a dedicated pallet allowing attachment to a free-flying space platform operating in low earth orbit. This pallet would also provide for integration within the shuttle cargo bay for launch and retrieval of the facility.

The facility will be capable of providing for multiple missions, each of approximately six months duration.

STARLAB will be configured as a general-purpose UV-optical astrono astronomical facility with emphasis being placed on achieving:

- High-angular-resolution imagery in wide fields
- Far-ultraviolet spectroscopy, extending down to the interstellar absorption limit at 90 nm
- Previsely calibrated spectrophotometry and spectropolarimetry over a wide UV wavelength range
- Solar system studies, including high-resolution synoptic imagery of planets.

The basic configuration of the facility will be as shown in Figure 2 and will consist primarily of a forward telescope housing and an aft instrument housing joined at a common annular structural ring. This central structural ring serves to mount the primary mirror, and also to provide the attaching points and indexing surfaces for the scientific instruments and other permanent fixtures of the facility. STARLAB is integrated to the Instrument Pointing System (IPS) by means of a two-bay truss structure which transmits the telescope load from the main structural ring to the Payload Integration Plant of the pallet.

The optical design of STARLAB will conform to the Ritchey-Chretien telescope shown in Figure 3. The 1 meter telescope comprises two hyperbolic mirrors, the primary at f/2 to yield an overall system focus of f/15. The system, when baffled, will have a linear obscuration ratio of not more than 0.35 and provide a 48 arc-min field of view and be designed to minimize aperture diffraction with wavelength in order to maintain the quality of the final image.

3. UNIQUE CAPABILITIES OF STARLAB

Science is currently moving at an accelerating pace toward one of the greatest philosophical achievements in the history of humanity -- a unified understanding of the total scheme of evolution of the universe. Space observatories, unencumbered by the Earth's atmosphere, will play a pivotal role by extending regular access to the entire electromagnetic spectrum emitted by astrophysical objects, by exploiting the superb impage quality available in the absence of atmospheric turbulence, and by probing the darkness of the night sky above the airglow.

STARLAB will make contributions to the resolution of a large range of scientific problems in astronomy, astrophysics, and cosmology.

Figure 4 is a wide-angle photograph (6^0 x 6^0) that shows the entire Large Magellanic Cloud galaxy and illustrates the dense star clusters and star clouds which require the high resolution provided by STARLAB, if their stellar and nebular makeup is to be studied in detail.

Some of the high priority scientific missions identified include:

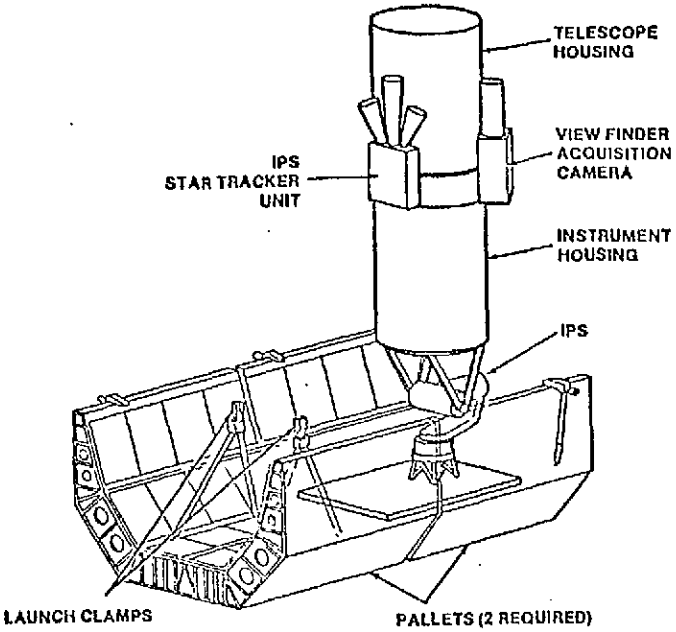


FIGURE 2. Starlab Integration with IPS on Spacelab Pallets

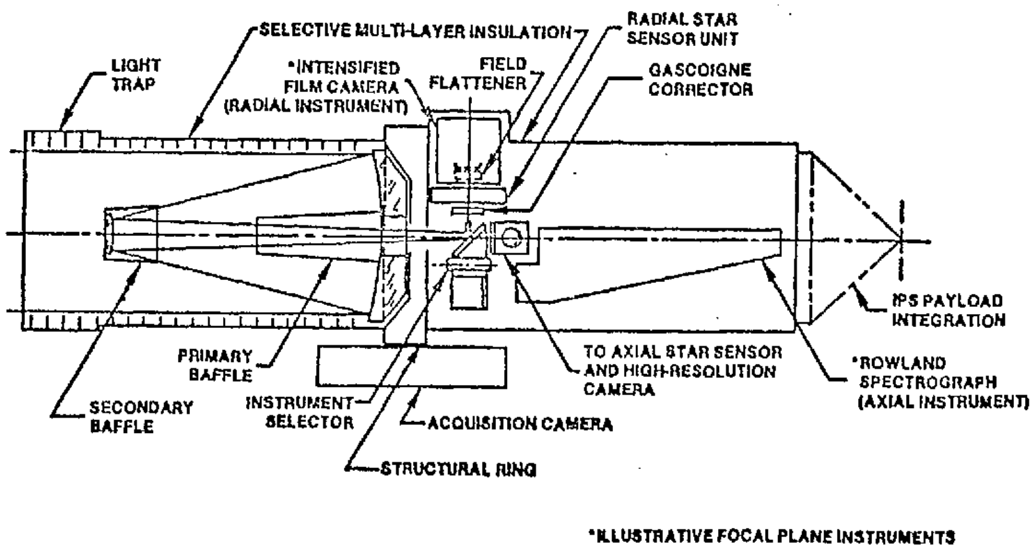


FIGURE 3. Starlab Telescope and Instrument Assembly

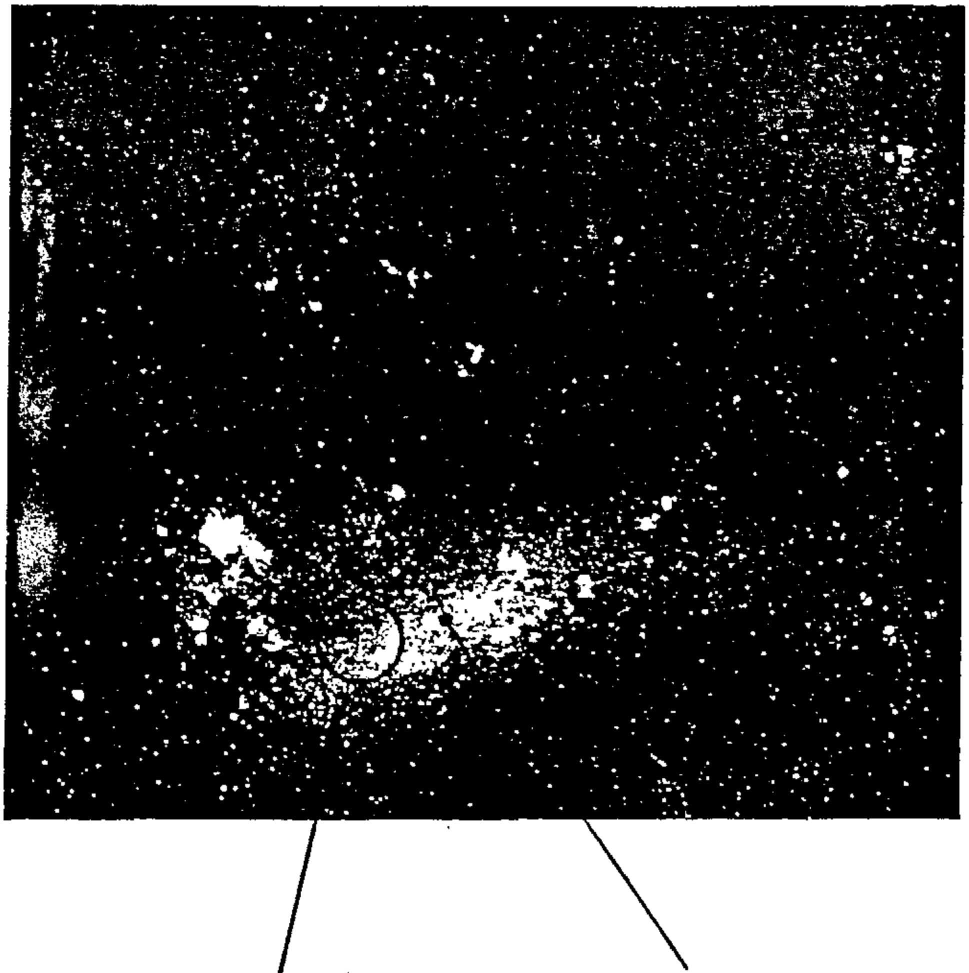


FIGURE 4 - FIELD OF VIEW COMPARISON

High Angular Resolution Imagery Over Wide Fields

STARLAB's greatest impact will be on problems requiring high resolution imagery over fields significantly larger than the 2.7 arc-min field of the ST camera. A great many important astrophysical problem areas fall in this category, ranging from advanced stages of stellar evolution in globular clusters (10 to 60 arc-min in diameter) to the history of star formation in nearby galaxies (400 arc-min for the Large Magellanic Cloud, 10 arc-min for the Virgo galaxies), to clusters of galaxies (17 arc-min at a redshift of Z = 0.3).

The Cosmic Distance Scale

STARLAB can make direct determination of the distances to many galaxies within 100 Mpc. The large statistical sample it will obtain with its large data field is essential to reliably account for the cosmic dispersion of each distance indicator.

Stellar Content of Nearby Galaxies

STARLAB will obtain an unprecedented amount of information on individual stars in nearby galaxies and hence their evolutionary history. At 100 kpc, stars intrinsically fainter than the Sun can be measured.

Ultraviolet Surface Photometry of Galaxies

Ultraviolet surface photometry of galaxies too distant for many individual stars to be resolved is of great intrinsic interest and is also fundamental for the interpretation of galaxy surface brightness profiles determined for high-redshift objects by ST.

Clusters of Galaxies

Even at high redshifts, clusters of galaxies are still about three times larger than the ST's field of view. STARLAB's large field and high resolution allow studies of both cluster dynamical evolution and evolution of individual galaxies in clusters at large lookback times.

Deep Extragalactic Surveys

A single STARLAB frame will contain thousands of galaxies at large lookback times, yielding much more statistical information on the early evolution of the universe than can be supplied by either ST or ground-based telescopes.

Stellar Evolution in Star Clusters

Large-sample colour-magnitude diagrams can be obtained for many globular clusters to $M_v = 10$, which can be used in understanding advanced stellar evolution.

The Interstellar Medium

STARLAB's high spatial resolution, wide field, and access to the ultraviolet are powerful tools for the study of interstellar gas and dust in our galaxy.

Wide-Field Spectral Imagery

The use of a grating plus prism combination ahead of the focal plane will yield a spectral resolution of 100 over the entire high-resolution field and allow a whole host of spectral survey problems to be done.

Solar System Studies

STARLAB will provide unique capabilities in studies of the solar system. Its spatial resolution on the planets will be comparable to data returned over short time intervals by fly-by planetary probes (e.g. Pioneer 10 and 11 on Jupiter). STARLAB will allow synoptic monitoring of long-term as well as day-to-day variations in planetary atmospheres. Narrow-band filters may be chosen to isolate specific spectral features so that they may be mapped over a planetary surface. STARLAB can fine-track on individual planetary features, obtaining spectral data as the planet rotates. It may be the only major telescope capable of observing Mercury and near-Sun comets, which are too close to the Sun to be safely observed by automated satellites. Illustrative applications of these capabilities include the mapping of distinct geological provinces on Mercury; determination as to whether the water-ice clouds associated with large volcanoes on Mars are caused by orographic uplift or by local source degassing, possibly associated with volcanic activity; and precise measurement of the wind fields on Jupiter to obtain a better understanding of the planet's general circulation. The wide-field, high-resolution imagery of comets in narrow bands will give the scale lengths which are the key to coma chemistry and will help to determine the place and physics of plasma production. Numerous other solar-system problems can be attacked by STARLAB, in support of planetary probes, to provide an advancing basis for understanding the origin and evolution of planetary systems.

4. PROGRAM STATUS AND COMMITMENT

The latest study conducted in the first quarter of 1981 has demonstrated first level compatibility between STARLAB and the free-flying platform SASP (Science and Applications Space Platform), the results of these findings being included as Appendix A. This reconfiguration of the operational mode for STARLAB has resulted in at least a 30 fold increase in cost-effective observation times.

The currently envisioned schedule would require STARLAB to be available for launch in the 1987-1990 time frame. This would require a firm commitment to be made to the program no later than early 1984. However, a number of system definition tasks need to be undertaken prior to this period in order to allow the most cost-effective implementation of the overall program and in addition, to ensure that full consideration be given to STARLAB as a viable payload in the evolution of SASP.

STARLAB enjoys the support of the Australian Scientific Community and is compatible with their industrial priority of developing space-qualified instrumentation. It enjoys the support of the American Scientific Community and is compatible with NASA spending envelope which precludes a scientific equipment purchase in parallel with Space Telescope but permits launch and operational support to be committed for the late 80's. It also enjoys the support of the Canadian Space Science Community and is compatible with the industrial priorities of Canadian Science policy.

5. BENEFITS TO CANADA

The program is completely compatible with Canadian Space Policy and is an ideal project on which to implement the Canadian industrial objectives of that policy.

Canadian industry has the experience and expertise to be prime contractor for the telescope facility and has available to it U.S. support in specialized areas, if needed to minimize any technical risk.

Current manufacturing and integration capability will ensure a high Canadian program content. The recent extension of the environmental test facilities at the David Florida Laboratory is well suited to satisfying the test requirements of this project.

Canada and Australia make a good match for sponsoring the capital costs of STARLAB as there is little overlap in industrial capability. Canada will enjoy the advantage of being the major industrial contributor and it is anticipated that considerable Australian funds will be channelled into Canada.

Canada, as supplier of the STARLAB telescope, stands to benefit immensely in foreign markets as a clearly identifiable prime contractor on a major international project with prestigious partners - a first such identification opportunity for Canadian industry.

STARLAB is an effective scientific concept for the conducting of space research. The scientific mission it is to address is valid and exciting and enjoys widespread support from the Canadian Scientific community interested in space who strongly endorse its development and intend to utilize it extensively.

Since STARLAB is now proceeding as a platform attached payload Canada has the opportunity to become intimately aware of, and involved in, the engineering of space platforms which will become the major building base for space developments of the future.

6. TRIPARTITE ARRANGEMENT

It is agreed that Canada would fulfill the role of prime contractor for the STARLAB Observatory, this being achieved through an arrangement similar to that in place for the Shuttle Remote Manipulator System (SRMS) program. The National Research Council of Canada, through the Canada Centre for Space Science, will be the project sponsor in Canada and be responsible for program management in Canada.

Canada would assume responsibility for the design and supply of the STARLAB telescope facility, including structures, optics, control and data handling, thermal and contamination control, systems software, and integration and testing of the telescope facility with the scientific instruments. In addition, Canada would also supply integration, mission and software support during integration of the telescope facility with the space shuttle and space platform, both NASA responsibilities.

Australia would be responsible for the development and supply of the first complement of scientific instruments and for providing support to Canada during the integration phase of the program.

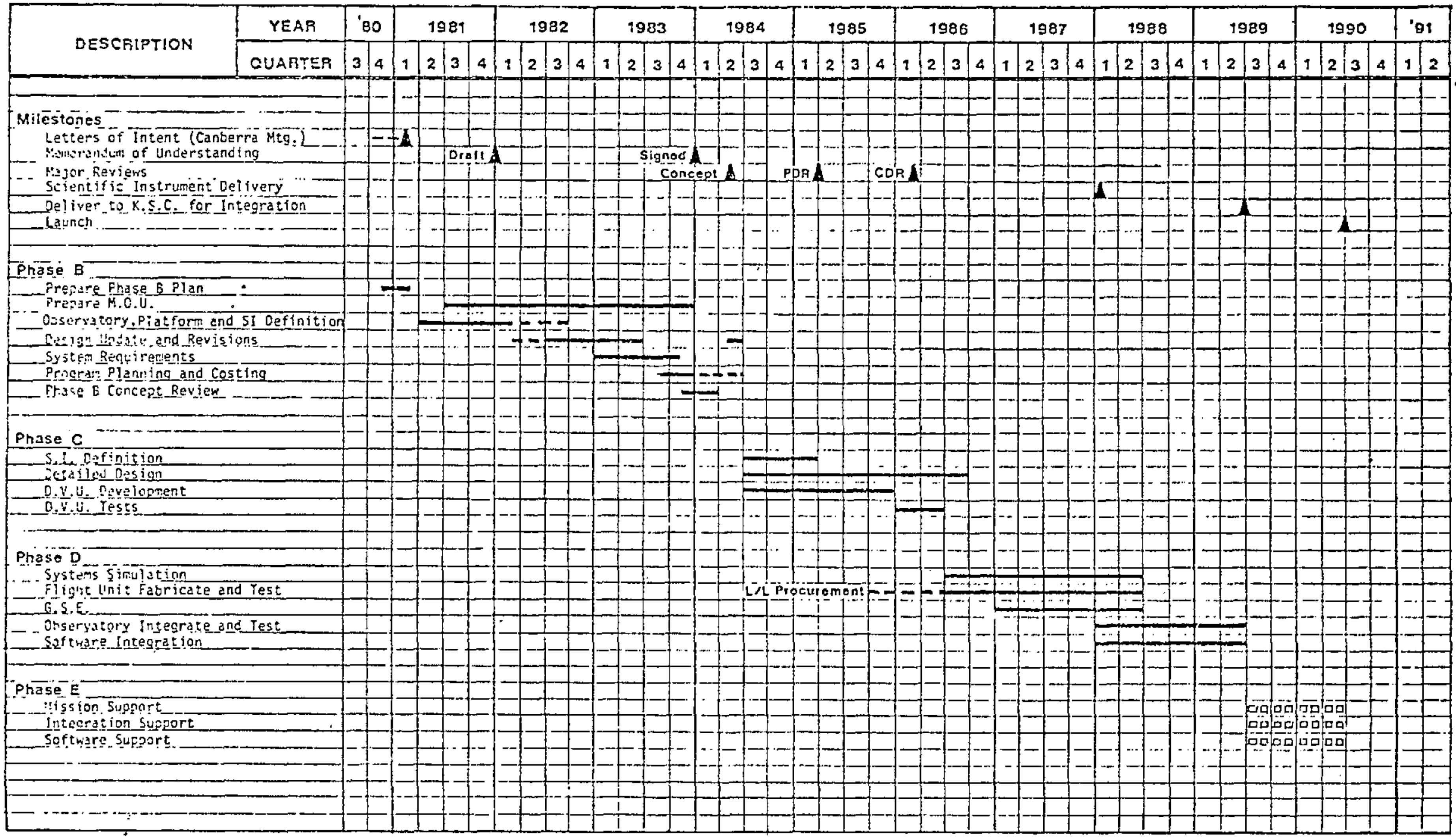
The United States portion of the program will be implemented through NASA. NASA would be responsible for the integration of STARLAB to the pallet and Instrument Pointing System, the pallet to the platform and the platform in the shuttle, and would provide the launch. STARLAB would likely not fully utilize the platform capability and so may be paired with another scientific mission that is compatible with the observational program planned for STARLAB. Canada, and to a lesser extent Australia, would provide technical assistance to NASA during integration and launch.

NASA would also provide the operational support of STARLAB while in orbit and receive the data at its ground stations. Analysis and study of this data would be the responsibility of the scientists of each country.

7. PROGRAM COSTS AND SCHEDULE

The cost of the STARLAB program, based on achieving the schedule shown in Figure 5, is estimated at between $110 to $135 M in Canadian dollars. This cost is shared between the three participating countries, the contribution of each being detailed in Table 1.

Table 2 provides an estimate of the cash flow requirements for the Canadian portion of the program for the concentrated effort required during Phases C and D.



Starlab Observatory Schedule

FIG. 5

TABLE 1

OVERALL ESTIMATED COSTS OF STARLAB TO TRIPARTITE MEMBER COUNTRIES

CANADA	- TELESCOPE FACILITY			
	Phase B	(1981-1984)	$ 1 - 2 M	
	Phase C/D	(1984-1989)	$40 - 50 M	
	Phase E	(1989 -)	$ 3 - 4 M	
				$44 - 56 M
AUSTRALIA	- INSTRUMENTS			$18 - 20 M
U.S.A.	- LAUNCH AND SPACE PLATFORM (SASP)			$30 - 40 M
			TOTAL PROGRAM COSTS	$92 - 116 M

Notes:

1. Costs derived from DSMA ATCON LTD. Report No. 1151/1122, Preliminary Study of STARLAB Canadian Costs and Industrial Participation, dated October 1980 and the Tripartite Meeting at Goddard Space Flight Centre, September 1980.
2. U.S.A. costs include an ROM allowance for SASP useage for which no cost data is at present available.
3. All monies are in 1980 United States dollars.

ACTIVITY	CALENDAR YEAR						TOTAL
	84	85	86	87	88	89	
S.I. DEFINITION	.13	.07					0.2
DETAIL DESIGN	0.9	1.7	1.3				3.9
D.V.U. DEVELOPMENT	1.6	3.2					4.8
D.V.U. TEST			2.1				2.1
SYSTEMS SIMULATION			.45	.9	.45		1.8
FLIGHT UNIT FABRICATION AND TEST			4.11	8.23	4.11		16.45
G.S.E.				2.47	1.23		3.7
OBSERVATORY I AND T					4.23	2.12	6.35
SOFTWARE INTEGRATION					0.93	0.47	1.4
PROGRAM MANAGEMENT	0.4	1.1	1.2	1.4	1.5	0.7	6.3
TOTAL	3.03	6.07	9.16	13.0	12.45	3.29	47.0

$ M (CANADIAN)

TABLE 2 - STARLAB OBSERVATORY CANADIAN CASH FLOW, PHASES C AND D

APPENDIX A

STARLAB/SCIENCE AND APPLICATION SPACE PLATFORM COMPATIBILITY

The following table combines the requirements of STARLAB with the capabilities of Science and Application Space Platform (SASP) to provide a first-order compatibility assessment. This comparison clearly demonstrates that no serious conflicts are anticipated, however, certain areas are in need of further study.

STARLAB/SCIENCE AND APPLICATION SPACE PLATFORM COMPATIBILITY

ITEM	STARLAB REQUIREMENT	SASP CAPABILITY	COMMENTS
1. MISSION ASPECTS			
1.1 Orbit Selection:			
Altitudes - KM	350/400/800	400/400/700	Compatible
Inclination - degrees	20/28/56	28.5/57/98	
1.2 Platform Orientation	Celestial viewing	Earth pointing/ inertial fixed	Inertially fixed mode of operation preferred. Additional viewing constraints if earth pointing.
1.3 Duration	6-12 months	6 years	Compatible
1.4 Availability	100% subject to orbit viewing limitation	100%	Satisfactory
1.5 Flight Schedule	1989-1991	1987-1990	Satisfactory
1.6 Turnaround Time	N/A	3 month revisit by shuttle	Flight schedule dependent
2. RESOURCE ASPECTS			
2.1 Power	-VDC 1 kW Average 1.3 kW Peak	30/120 VDC 20 kW Average 30 kW Peak	Satisfactory - subject to power requirements of other payloads.
2.2 Thermal	Unknown	Centralized heat dissipation provided	Definition of heat dissipation required. No major problem anticipated.

ITEM		STARLAB REQUIREMENT	SASP CAPABILITY	COMMENTS
2.3	Telemetry/Data Handling	7 Mbps	'S' band 12 Mbps 'K' band 30 Mbps Single axis channel TDRSS	Satisfactory
2.4	Control & Stability	1 arc-sec / .02 arc-sec	1 arc-sec/1 arc-sec with IPS	SASP compatible with addition of IMC
2.5	Weight	2000 kg	See Comments	Compatible,subject to other payloads.
3.	OPERATIONAL ASPECTS			
3.1	Servicing	See Comments	3 month shuttle revisit	1 month if on board film requirement reinstituted
3.2	Deployment & Retrieval	RMS and EVA	RMS and EVA	Satisfactory
3.3	Viewing Constraints	100%	Berth and configuration dependent	Virtually 100% achievable on 2nd order SASP and specific berths on 1st order
3.4	Contamination	TBD on mission and operation	Environment more benign than shuttle	Further study required - system may be required to be shut down during 3.6
3.5	EMI/EMC	Unknown	Minimal - as good or better than shuttle	Further study required

ITEM		STARLAB REQUIREMENT	SASP CAPABILITY	COMMENTS
3.6	Platform Manoeuvring and Station Keeping	N/A	Orbit correction required every 3 months	System shutdown may be required for contamination control and dynamics
3.7	Dynamic Interaction	0.1 to 1 Hz max. IPS sensitivity	N/A	Level of interaction unknown
3.8	Checkout	Checkout with shuttle docked configuration	SASP has docking capability	Satisfactory