MARKET FEASIBILITY STUDY
OF
SPACECRAFT DEPLOYABLE SOLAR ARRAYS

for

REMOTE MANIPULATOR SYSTEMS DIVISION
SPAR AEROSPACE LIMITED
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EXECUTIVE SUMMARY

MARKET FEASIBILITY STUDY OF SPACECRAFT DEPLOYABLE SOLAR ARRAYS

A study to determine the marketability of RMSD's solar array systems technology has been completed by Philip A. Lapp Ltd. The work effort which included field trips to six major U.S. spacecraft primes, has resulted in the gathering of a significant amount of marketing information, from which important conclusions re RMSD's future marketing strategies can be derived. The following summarizes the major facts learned and the resultant conclusions that have been drawn.

- RMSD is viewed by the spacecraft prime community as a technical "centre of excellence" for the supply of spacecraft hardware. The primes visited, spoke very highly of RMSD's capabilities, particularly in the mechanisms area.

- RMSD's lack of complete vertical integration, e.g., manufacturing and cell laydown, is not viewed by the primes as a significant factor, provided overall program cost and schedule areas remain competitive.

- Primes that currently maintain a state of the art solar array design capability (RCA Astro, Ford Aerospace,TRW, LMSC) expect to retain solar array systems in house unless other systems show a significant overall cost benefit (e.g. 25%). The sub-contracting of mechanisms and components is, however, often considered.

- The vast majority of future spacecraft solar arrays will be rigid panel systems. Although this technology is not currently developed within RMSD, its credentials have been established through the successful development and flight operation of the more complex flexible blanket array system.

- No clear 'niche' for RMSD is currently identifiable in the overall deployable solar array market place. When one relates this to the expected future markets, which will be very price-driven, RMSD must continue to use 'leverage' to ensure low front-end development cost to a customer.

- A 'niche' in the mechanisms area appears to exist since some primes (a) acknowledged RMSD's high competence in this field and (b) requested input from RMSD re some of their mechanism concerns.

CONCLUSIONS:

There is a viable solar array and space mechanisms business for RMSD in the U.S., but to be successful RMSD must:

1. Continue its present thrust to develop a rigid panel array system within an umbrella Corporate Development Agreement with the Canadian Government and win solar array contracts on the Hughes HS 394 or Leasecraft programs.

2. Maintain a flexibility of design (modularity) in the developed rigid panel system such that it can be adapted to varying spacecraft interface and power level needs with a minimum of design (and supporting equipment) change.

3. With these elements in place, an aggressive marketing effort should result in a high probability of capture of other array systems.

4. Capitalize on the interest expressed in RMSD mechanisms capability through the development of a mechanisms marketing plan and continued dialogue with potential customers re their needs.

RECOMMENDATIONS:

1. RMSD mount an aggressive marketing and related R and D program directed toward the attainment of a dominant position as a solar array subsystem supplier.

2. RMSD make regular and continued visits to major prime contractors at the working level within an overall solar array marketing strategy.

3. RMSD coordinate with SASD and Astro Research its marketing efforts with respect to spacecraft prime contractors.

4. Anticipated and identified future needs for solar array and related mechanisms needs be the subject of RMSD R and D activities in order that Spar's technology leads the requirements.

5. Vertical integration of the solar array activity, including cell manufacture, mounting and blanket laydown, be based solely on internal make/buy considerations because the market appears to be insensitive to such issues.

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CHAPTER 1

1. INTRODUCTION

1.1 Background

As an element of the process of developing strategies for the growth and development of the Remote Manipulator Systems Division (RMSD) the management group of the Division require an analysis of the market that might be available to RMSD in the role of an independent specialist supplier of solar-arrays.

In this context the study has two objectives:

1. to test the hypothesis that a) spacecraft bus suppliers and prime contractors do not need to maintain in-house deployable solar array supply capability, and that b) such solar arrays can be purchased more efficiently from a separate specialist supplier;

2. to determine if there is a niche for RMSD as a specialist supplier of deployable solar arrays in the general power range 2.5 - 25 kw.

The Work Statement for the study is included as Appendix 1.

1.2 Conduct of the Study

In this study the contractor has examined the capabilities, activities, and track record of RMSD in the deployable solar array field. The world market model maintained by RMSD has been examined and the probable available market relative to RMSD has been

postulated. Attitudes, preferences, and customs of major spacecraft prime contractors have been elicited through field trips to the following companies:

- Fairchild Space Company
- Ford Aerospace and Communications Corporation
- Lockheed Missiles and Space Corporation
- TRW Systems
- Rockwell International
- RCA Astroelectronics

In these field trips a stand-up presentation with visual aids was made by the study group which presented SPAR and RMSD as having special capabilities and advantages in offset and international trade that could be attractive to prime contractors. The visual aids used in the presentation are displayed in Appendix 2.

1.3 Assumptions and Parameters

In carrying out this study the contractor made certain assumptions about RMSD which have significance in the conclusions that are arrived at in this report.

a. It has been assumed that RMSD would pursue initiatives in areas in which RMSD has established competence. This is to say that the Division would be more focussed upon the exploitation of current strengths and products than upon breaking into new areas of activity which would be inappropriately expensive, or areas in which competitors already have strongly established positions.

b. In conducting this analysis we are aware that SPAR is a company in which a strong element of its success has been derived from Government support of non-recurring engineering costs and in which off-shore sales have been assisted by Government intervention and initiatives. In this context the Company has had limited experience in competing on its own in price-sensitive markets. It is our assumption that a SPAR corporate thrust will be to continue in this mode and that the Company will pursue off-shore sales with considerable reliance upon the political process for support.

c. We are assuming that RMSD which is not a manufacturing house would not propose to become a manufacturing house. We are aware that RMSD does not reflect a total capability as a potential supplier of spacecraft deployable solar arrays but does have particular strengths which do not rule out its viability as a solar array subsystem prime contractor.

1.4 Report Framework

In addressing the objectives of the study; the hypothesis that solar array procurement can be more efficient when prime contractors purchase ex-house from an independent supplier; and the question as to whether

there is a niche in the industry market for RMSD, the major factors to be considered are the following:

a. RMSD experience, track record and credibility;
b. RMSD particular technical strengths;
c. Price competitiveness and cost minimization;
d. Market volume, market character and requirements;
e. Capability for timely market response;
f. Technical competitiveness in terms of "true" competitors;
g. Market demand anticipation;
h. Market strategy and activities;
i. Corporate support and integration.

Consequently this report addresses the foregoing issues in chapters as follows:

CHAPTER 1 - Introduction

CHAPTER 2 - RMSD Solar Array Capabilities, Activities, and Achievements

This chapter outlines briefly RMSD solar array activities and the particular strengths of RMSD applicable to solar arrays.

CHAPTER 3 - Scope and Character of the Spacecraft Solar Array Market

This chapter reviews the world market model maintained by RMSD and identifies the most likely opportunities for RMSD. Attitudes, preferences and customs of prime contractors in contracting-out are analysed.

CHAPTER 4 - Conclusions and Recommendations

This chapter summarizes the conclusions which are the most significant in the context of the objectives. Strategies are recommended.

CHAPTER 2

2. RMSD SOLAR ARRAY CAPABILITIES, ACTIVITIES AND ACHIEVEMENTS

2.1 RMSD EXPERIENCE

While SPAR AEROSPACE in general, both on its own and in combination with RCA, has been prominent in the space industry the role played by the Company has been relatively limited taken in terms of the total space industry. Highlights of SPAR's role in the solar array field have been HERMES (CTS), and the current L/SAT (OLYMPUS) program. Early work had been carried out in collaboration with Hughes Aircraft on the flexible roll up solar array (FRUSA). Opportunities may now be emerging in the production of solar arrays for Hughes' 394 spacecraft (probably rigid array) and with Fairchild Space Company in the Leasecraft program. The SPAR/RMSD experience has largely been in the area of flexible arrays rather than in rigid arrays.

In its programs to date RMSD has specialized primarily in the flexible array field; and has not produced solar cells, mounted cells nor performed cell laydown on solar blankets. RMSD has taken the responsibility for design engineering and dynamic analysis of solar arrays, has performed solar array system assembly, integration and test, but has not done manufacturing in any substantial measure.

The evolution of the solar array relevant RMSD Technology Base primarily derives from Alouette and ISIS (DOC), and CTS (DOC) consisting of spacecraft

structures, flexible deployable arrays, array drives, extendible mechanisms, attitude control, thermal design, array simulation and dynamic analysis. Current activities include development of the OLYMPUS flexible deployable array, studies of high-power array drives (DOC), constant speed drive (INTELSAT), high power retractible flexible array development, concentrator array studies, and large rigid panel array development. In-house R&D programs are being conducted in array power performance, high voltage arrays, shadowing studies and the structural testing of deployed arrays.

SPAR AEROSPACE as a corporation has a considerable track record in the spacecraft industry as reflected in Table 1 involving 30 spacecraft projects of which 19 have been with five major prime contractors (Lockheed 1, RCA 5, Hughes 11, BAE 1, TRW 1) and 11 with national governments (CDA 7, US 3, BRAZIL 1). Three of these programs have involved solar array work.

2.2 RMSD Capability

RMSD, in describing its own capabilities at a strategic planning seminar in 1983 provided the following profile of its character and capability:

- the Division does not have a product of any sort in place
- the Division has a unique and highly skilled problem solving capability
- the Division has a good application capability
- the Division has a good engineering analysis and hardware design capability in space applications

TABLE 1

SPAR SATELLITE SYSTEM/SUBSYSTEM EXPERIENCE

TIME FRAME	PROGRAM	PRIME	SUB	SUPPLIER	CUSTOMER
	RELAY		X		RCA
	ALOUETTE I			X	CDN GOV'T
	PEGASUS			X	U.S. GOV'T
	EXPLORER XX			X	U.S. GOV'T
1960	ALOUETTE II	X			CDN GOV'T
TO	ISIS I	X			CDN GOV'T
1972	ISIS II	X			CDN GOV'T
	INTELSAT IV			X	HUGHES
	HERMES CTS	X			CDN GOV'T
	ANIK A			X	HUGHES
	FRUSA			X	HUGHES
	WESTAR I			X	HUGHES
	INTELSAT IV A			X	HUGHES
	COMSTAR			X	HUGHES
	SATCOM I		X		RCA
	PALAPA A			X	HUGHES
	ANIK B		X		RCA
1973	ORBITER		X		U.S. GOV'T
TO	TDRSS		X		TRW
1980*	SBS			X	HUGHES
	ANIK C		X		HUGHES
	ANIK D	X			CDN GOV'T
	SARSAT		X		CDN GOV'T
	WESTAR II			X	HUGHES
	SATCOM II		X		RCA
	PALAPA B			X	HUGHES
1980	OLYMPUS		X		BAE
TO	G STAR		X		RCA
DATE	BRAZILSAT	X			BRAZIL GOV'T
		6	10	13	

* EXCLUDES INTELSAT V (LMSC) (DRIVE & DEPLOYMENT DESIGN)

- the Division has essentially no manufacturing/ fabrication facility/plant/machinery but has developed sources of hardware supply
- the Division has a proven ability to carry out major advance technology development programs.

In the solar array context the Division profiles itself as having the capability to:

- analyse and develop specifications for rigid and flexible solar array subsystems
- design, procure, integrate and test complete solar arrays and related mechanisms,
- analyse, design, specify and test solar array deployment systems including STEMS and Astromasts, and associated electronics
- design, develop, assemble and test solar array track and drive mechanisms including related electromechanical devices and electronics
- analyse, design and specify solar array cell configurations and their power performance characteristics
- conduct detailed analyses and simulations of solar array/spacecraft interaction dynamics
- design and development of mechanical and electromechanical mechanisms in general
- analyse and simulate spacecraft structural and thermal performance
- conduct flexible body dynamic analyses, particularly for spacecraft with large, flexible appendages.

The profile of the RMSD character and capability that emerges from the foregoing, and which is to be fitted to the market place, is one in which RMSD would focus its

thrust on the exploitation of established strengths, and could be described as follows:

> A highly specialized solar array subsystem designer and integrator with particular strengths in spacecraft mechanisms, sophisticated engineering analysis, total subsystem integration and test, program management and control, with a particular emphasis upon flexible, deployable solar arrays.

It is noted that this profile does not include the following in-house capabilities which would constitute a total in-house subsystem capability:

- manufacturing including cell substrate fabrication
- cell production
- cell laydown on substrate
- Astromast and STEM technology

Our interviews and discussions with spacecraft prime contractors did not indicate that the absence of the first three capabilities would be a serious factor in considering RMSD as a viable solar array subsystem or component supplier. In part this positive attitude reflects the preference to purchase a total subsystem package in the "buy" option of the make/buy decision. It appears to be of little consequence to the prime contractor who does the fabrication, just as long as the supplier meets performance, price and delivery requirements.

Astromast and STEM technologies available from Astro Research complement RMSD capabilties within the Spar corporate family. These technologies and related mechanism design capabilities at Astro Research are highly respected among spacecraft prime contractors, and thus enhance Spar's credibility as a solar array supplier.

The following Chapter consists of an analysis of the potential solar array market in terms of RMSD strengths and prime contractor attitudes.

CHAPTER 3

3. SCOPE AND CHARACTER OF THE SPACECRAFT SOLAR ARRAY MARKET

3.1 General Nature of the Solar Array Market

Up to now, the solar array market has been driven mainly by communications and remote sensing applications, which have been met adequately with relatively low-power rigid solar arrays. The near-term situation is that rigid arrays will continue to dominate the market place, and the power threshold beyond which flexible arrays are preferable is likely to creep up beyond the present consensus of 6 kw. RMSD has not had extensive experience in rigid arrays; its main thrust has been in the direction of flexible arrays.

It would seem, on the surface, that RMSD strengths and relevance are more related to the next evolutionary step in the space industry which is somewhat further out in point of time (perhaps beyond 1990 in any substantive form). This evolutionary step involves the utilization of spacecraft as platforms for the conduct of physical, mechanical, and chemical processes and functions, including the performance of industrial processes in space. In this role power becomes a primary product of the spacecraft - in addition to providing a platform, the spacecraft bus becomes a power producer essential to the activities to be conducted.

Such power requirements can be substantial and create the demand for high levels of cost effective technology for power production. In terms of present technology

this requirement leads to the consideration of flexible panel arrays of greater size and output. Size factors demand advances in deployment, drive mechanisms and array attitude control systems. Higher power production leads to a consideration of more effective solar cells, substrates and blanket technology. Examples of this new evolutionary step in the space industry are the Fairchild Leasecraft and Space Station concepts.

Our discussions with spacecraft bus prime contractors indicate they are not anxious to consider flexible blankets below the 6 KW level unless there are compelling reasons. In the interests of price and the minimization of "up-front" customer cost, the major spacecraft bus suppliers visited were highly dedicated to the utilization of existing, proven and effective technology at the lowest achievable price.

3.2 Market Model

The market model that has been prepared and is maintained by RMSD has been examined by the contractor in some detail. This model portrays the magnitude and volume of the market (excluding military), as RMSD sees it, including all spacecraft irrespective of solar array type and power level requirements. A separation of this market into Canadian, U.S. and foreign spacecraft is summarized in Table 2.

The probabilities of RMSD being the solar array supplier for Canadian spacecraft is much higher than for participation in other spacecraft projects. Rigid arrays dominate the Canadian market since almost all of the communication satellites call for such arrays. Only Radarsat, two of which are planned, will use a flexible blanket array.

TABLE 2

EXPECTED CANADIAN SATELLITE MARKET (1)

1985 - 1997

SPACECRAFT	STATUS	ARRAY TYPE	LAUNCH DATES
ANIK F (Telesat J,L,M.)	3 follow-on	2 Rigid 1 TBD*	1987, 1989, 1992
ANIK E (Telesat K,N.)	2 follow-on	1 Rigid 1 TBD	1990 1993
TELESAT DBS	2 follow-on	2 Rigid	1992, 1993
M-SAT	3 proposed	2 Rigid 1 TBD	1987, 1991, 1994
RADARSAT	2 proposed	2 Flexible Blanket	1990, 1995
(12) TOTAL SATELLITES	7 follow-on	5 proposed	
ARRAYS	7 rigid	3 TBD	2 Flexible

*TBD - To be determined

(1) Spar Aerospace Prime Contractor

TABLE 2 (Cont'd)

SPAR - RELEVANT U.S. SATELLITE MARKET

1985 - 1998

SPACECRAFT	STATUS	ARRAY TYPE	LAUNCH DATES
Miscellaneous DBS	14 follow-on (DVS, USSB, CBS)	14 Rigid	1986, 1987, 1988, 1989, 1994, 1995, 1996
ISO-Electric Focusing Production (Private Sector)	13 forecast	1 Rigid 12 TBD	1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998
Electrophoresis Operations in Space (MDAC/J&J)	34 proposed	6 Rigid 28 TBD	1989, 1990, 1991, 1992, 1993, 1994, 1995, 1997, 1998
(61) TOTAL SATELLITES	14 follow-on, 34 proposed, 13 forecast - 61		
ARRAYS	21 Rigid, 40 TBD		

*TBD - To be determined

DOES NOT INCLUDE U.S. MILITARY MARKET

TABLE 2 (Cont'd)

SPAR - RELEVANT EUROPEAN SATELLITE MARKET
1985 - 1997

SPACECRAFT	STATUS	ARRAY TYPE	LAUNCH DATES
OLYMPUS/L-SAT/ ESA	2 contracted 2 follow-on	4 Flexible	1986, 1987, 1991, 1995
OLYMPUS/L-SAT/ OTHER	9 forecast	9 Flexible	1989, 1990, 1991, 1992, 1993, 1995, 1996, 1997
EURECA/ESA	1 contracted 3 forecast	4 Flexible	1987, 1990, 1993, 1996
NORDCOM	2 proposed	2 Flexible	1987

TOTAL SATELLITES (19) - 3 contracted, 2 follow-on, 2 proposed,
12 forecast - 19
ARRAYS - 19 flexible

(1) Spar Aerospace Prime Contractor

*TBD - To be determined

TABLE 2 (Cont'd)

SUMMARY SPAR - RELEVANT EXPECTED SATELLITE MARKET
1985 - 1998

SPACECRAFT	ARRAY TYPES
3 Contracted	28 Rigid
23 Follow-on	21 Flexible
41 Proposed	43 To be Determined
25 Forecast	
92	92

DOES NOT INCLUDE U.S. MILITARY MARKET

ESTIMATED VALUE SOLAR ARRAY MARKET $1.4 BILLION (1984)

Condensed from
RMSD Market Model
January 1984

In respect of the United States market (61 spacecraft), 14 spacecraft solar arrays are stipulated as rigid, 47 To Be Determined, none are stipulated as flexible. Many of these spacecraft are in communications roles with relatively low power requirements.

The European spacecraft market in which RMSD could find a niche would likely be limited to follow-on Olympus (L/SAT) bus orders with the SPAR/RMSD involvement covering the activities and elements of the current Olympus contract - tiptension mechanisms, secondary deployment electronics, interleaves parking spring, integration of hardware and components, and integrated system testing. There is no automatic assurance that follow-on Olympus bus orders would provide the same role of RMSD as does the initial contract however. The European array market tends toward flexible systems, in contrast with the North American market. This may be the result of selecting only those satellite programs that are Spar - relevant.

The market model would appear to confirm the following:

1. The industry does not favour flexible arrays below the cost effective crossover point (currently 6 kw). Thus the effective flexible, deployable solar array market extends from 6 kw upwards. This eliminates most of the proposed and follow-on communications spacecraft of current epoch from the flexible array market (with the exception of Olympus).

2. The market applicable to RMSD for higher power flexible solar arrays appears to be limited to:

   a. Possible follow-on Olympus;
   b. Leasecraft (still to be determined);
   c. Space Station (not currently in RMSD model);
   d. High power producing spacecraft designed for the performance of R&D and industrial tasks for which requirements are just beginning to emerge.

Considering the time factors involved in converting ideas related to c. and d. into program plans, it would appear that the role for RMSD as an independent specialist supplier of high-power flexible solar array subsystems is very limited in the mid-term timeframe (1995), except for the Olympus market. However, while there may not be a sufficient market in high-power flexible arrays to justify RMSD establishing itself as a specialist house in this type of array, we believe that there is a niche for RMSD in the solar array subsystem field.

There is the rigid array market which is here and now. Recalling the capabilities and particular strengths of RMSD in activities and elements of solar array subsystems reviewed earlier in this document, previous relationships with major spacecraft prime contractors, our interview/discussions with these contractors, and RMSD's success with the Canadarm, Spar has established a high degree of credibility among major space contractors. It is true that RMSD has not flown a rigid array. However, Spar has performed the far more

difficult task of developing a flexible array that has been proven in flight (CTS). In effect, Spar has established its solar array credentials, and we discerned that it is credible in either the rigid or the flexible array markets.

3.3 Interview Findings

Based upon our discussions with major spacecraft suppliers concerning the make/buy decision process, "buy" decisions are based upon:

a. procuring a product or service from a sub-contractor for approximately 25% less cost than the Company would experience doing the work in-house; this differential is needed to offset the costs of creating more formal specifications and drawings required to contract out;

b. procuring engineering and/or analytic services directed to the resolution of technical issues in which the Company does not have the immediate relevant expertise. This implies that the sub-contractor has already done it successfully - at least once;

c. procuring components, bits and pieces that the sub-contractor already has or which are close enough to what the sub-contractor has that it is more efficient to buy than to make;

d. overloading of in-house facilities.

Evidence of these opportunities during the field trips took the form of a considerable interest on the part of the major contractors in respect of Spar capability in spacecraft mechanisms (strengthened by the success of the CANADARM) with special focus on deployment mechanisms for solar arrays - Astromast particularly. (Lockheed, TRW and Rockwell also had interest in hardware bits and pieces such as "SPINNUTS").

From our discussions, it was evident that the prime contractors would be reluctant to contract out a total subsystem where there is a significant component of new development involved. It was argued that the prime wants to maintain close technical control, especially when new technology is introduced, and thus is likely to retain such work in-house. However, where the article deviates only in a minor way from a successful and proven design, and the subcontractor has established a track record, contracting can be attractive.

In the context of the foregoing, the responses that the Study Team received in their visits to spacecraft bus prime contractors led to the following perceptions:

a. Ford Aerospace and Communications Corporation has established its traditional suppliers in the spacecraft industry, and does not propose to shift from that position.

b. Fairchild Space Company has a requirement for high-power arrays and is conducting research and development on the trade-offs between 10 KW rigid panel modules vis-à-vis flexible panels. Flexible panels may have technical problems in the Leasecraft

role and may be more expensive than a rigid array with which they seem to be more comfortable. If weight is not critical, a retractible rigid array is likely to be chosen.

c. Lockheed is of course interested in and are involved with flexible deployable arrays, but would be reluctant to contract out a total subsystem when there is a considerable in-house capability. They would take advantage of Spar mechanisms competence however.

d. TRW have an interest in flexible deployable arrays but also did exhibit some reluctance about contracting out a total subsystem. They point to their particular strengths in complex dynamics analysis. They have an active interest in space hardware at the "bits and pieces" level. They feel that there is a basis for business with Spar in space mechanisms.

e. Rockwell International has a very active interest in high power arrays and in this context are highly interested in Olympus experience. They are quick to point out, with so much of their business being military, that a sub contractor would have to conform to Military Standard 1540. They place a lot of emphasis on rapid retractibility for the Space-Based Surveillance System.

f. Lockheed, TRW and Rockwell have great interest in Space Station and have assigned Special Space Station Program Managers.

g. RCA Astro Electronics mount, assemble (solder) and test their own solar arrays, and state they have been unable to find a subcontractor who can do the work as cheaply as they can do it for themselves.

A number of specific opportunities were uncovered during the visits. They are not recounted here, but were brought to the attention of RMSD management for whatever immediate action was needed.

3.4 Characteristics of the Solar Array Market

On the basis of the interviews and discussions with prime contractors, certain significant characteristics of the market emerge:

a. Prime contractors do not accept the hypothesis that it is not necessary to maintain an in-house solar array capability. However, they do acknowledge that it can at times be more efficient to purchase arrays from a specialist supplier.

b. The market is extremely price sensitive.

c. Prime contractors wish to avoid the very expensive "specification and drawing formalization" process that is involved when sub-contracting for a total subsystem. This cost could conceivably represent up to 25% of the total sub-system cost.

d. Prime contractors are dedicated to minimizing the up-front cost to the user and are resistant to adopting new technologies and complex solutions when simple ones will do. They will continue to favour rigid panel arrays whenever they can on the basis that they represent least risk.

e. Prime contractors in general have no inhibitions to contracting out for components but are more resistant to consider contracting out for total subsystems. They conduct considerable R&D in order to shape their decision process with respect to the subsystem, and want to maintain close control of the technology.

f. Prime contractors are in favour of contracting out for components, bits and pieces that conform to their overall system requirements if there is a sub-contractor who already has what is needed, and can provide it at an attractive price.

g. Most of the prime contractors have space mechanism sub-contractor relationships which have been in existence for some time, and with which they are comfortable. Firms that have been mentioned are Ball Aerospace, Shaeffer Magnetics, Aeroflex.

h. Almost all prime contractors express a considerable interest in Astromast technology and applications.

i. The general consensus among the prime contractors contacted is that solar cell production and cell laydown is not an essential capability for a sub-contractor. The belief seems to be that present potential output of existing suppliers already exceeds total market demand, and that some suppliers survive only because of the heavy support provided to them by their governments.

3.5 RMSD Market Opportunities

Taking into consideration the potential satellite market relevant to RMSD reflected in Table 2, the market can be divided into two main segments:

a. With the exception of Leasecraft, a continued emphasis on communications satellites through the 1990's which will almost exclusively involve rigid panel arrays. (The exception is Olympus.) This includes the HAC 394 for which the power range will likely not exceed 5 KW and for which rigid arrays are already stipulated. In the Leasecraft program, the current thrust is also to modular rigid panel arrays using large solar cells for which a flexible blanket may be unsuitable.

b. Future space station and power-producer spacecraft for commercial and military applications in the 1990's and beyond, requiring high-power deployable (and probably retractible)

flexible panel arrays. In this area requirements are only beginning to be perceived and understood.

The best current opportunities for RMSD lie in Segment a. This is the segment however in which RMSD has least experience and track record. Segment b. in which RMSD has a major technology lead is too far out in terms of time horizon. Furthermore it might be argued that in order for SPAR to exploit its deployable flexible array technology when such requirements arise, it will be essential to have had a role and capability in rigid panel array work.

The following Chapter will attempt to put the significant content of the foregoing chapters together to suggest a strategy which RMSD might follow in securing a niche in the spacecraft market as a solar array supplier to major spacecraft prime contractors.

CHAPTER 4

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Introduction

Chapter 2 of this document has postulated a profile of RMSD as a specialist house in some of the component elements of spacecraft deployable solar array subsystems. Chapter 3 has provided a view of the potential market which might be available to RMSD together with an appreciation of the motivations and preferences of the major prime contractors who form that market.

This Chapter returns to the two objectives of this study: the hypothesis and the solar array market niche for RMSD.

4.2 Validity of the Hypothesis

The hypothesis consist of two parts, the first is that spacecraft bus suppliers and prime contractors do not need to maintain in-house deployable solar array capability. We found the marketplace divided on this issue, a division that is based on the generic roots of the prime.

We visited three companies that were basically electronics in origin - Ford, TRW and RCA. These and similarly rooted companies traditionally select the

"make" option and do everything possible in-house, at least wherever it is practical and politic. A major exception is when the company forms part of an international consortium where a pre-negotiated division of effort has been worked out. An example would be the relationship where MBB supplies solar arrays to Ford. For these companies, the first part of the hypothesis is not valid.

The other three companies emerged from being essentially aircraft manufacturers - Lockheed, Rockwell and Fairchild - where subcontracting practices have been quite different. The aircraft industry is built upon supplier tiers, and unlike the electronics industry, no aircraft company in recent history ever had the capability of doing everything in-house. Thus such firms are more attuned to the "buy" option and it is natural for them to subcontract major subsystems to outside suppliers. (For example, airframe manufacturers worldwide depend on independent engine suppliers.) So it is with satellites, we found the aircraft-style companies less wedded to the need for maintaining in-house solar array supply capability. Lockheed was an exception where an independent business unit was established to exploit what was thought to be a market opportunity. This operation may be abandoned unless business prospects improve.

We conclude that the first part of the hypothesis is not valid for electronics-based prime contractors, but is valid for airframe-based contractors.

The second part of the hypothesis is that solar arrays can be purchased more efficiently from a separate specialist supplier. The validity of this statement depends on the technology base of the prime contractor, that is the investment in human skills and capital facilities, program loading and historical practices. Thus, like the first part of the hypothesis, the validity of the second part will vary from prime to prime.

While it costs extra to subcontract, and a suggestion has been made that the additional costs to formalize specifications and drawings could amount to 25%, there are offsetting savings in the reduction of charges for carrying the required human and capital investments needed to do the work in-house (i.e. to maintain the in-house infrastructure). However, some in-house expertise and R and D activity is still needed for the prime contractor to buy effectively, and provide the guidance and control all prime contractors claim to be essential.

For the airframe-based contractors, the second part of the hypothesis is valid. Judging by the fact that both Ford and TRW have contracted out solar array subsystems in the past (Ford to MBB, TRW to Ball Aerospace), one might assume that it is valid for them as well. However, while Ball Aerospace won TRW's GPS array drive (from Spar) on price, the Ford-MBB relationship was politically driven. RCA has always built its arrays in-house. Thus we conclude that while the second part of the hypothesis may be valid for TRW, it is not likely to be valid for Ford and definitely not valid for RCA.

4.3 Market Niche for RMSD

The hypothesis is neither the sole, nor perhaps even the most important basis for an RMSD strategy in the solar array business. RMSD's presence in this market so far has been the result of corporate leverage, at least with respect to its participation in the Hermes and Olympus programs. The continuing ability of the company to make "deals" involving solar array supply as part of a larger package (such as the HS 394) would appear to be a key factor in any future solar array marketing strategy.

Without exception, those visited stressed the pricing aspect as being the main driver in their solar array supply decisions, which came as no surprise. Despite the exchange rate advantage, price competitiveness is not a Spar strength. However, there are various ways in which Spar can reduce non-recurring engineering costs using a strategy that could carve out a niche in the competitive solar array market.

For RMSD, the solar array market can be divided into two parts:

a. Spacecraft programs where RMSD has a leveraged advantage due to Spar corporate arrangements usually involving other divisions such as SASD. An example is the HS 394.

b. Spacecraft programs where there is only direct, commercial, head-to-head competition. An example would be the Fairchild Leasecraft.

In the near and mid-term market (to 1995), the principal requirement is for rigid solar arrays where RMSD has no proven design, and thus where there will be significant non-recurring costs. It follows that if RMSD could standardize in some way on a rigid array modular design through a Type a. program such as HS 394, a portion of the non-recurring costs might be eliminated from a Type b. program and thus render RMSD more competitive. This presupposes the adaptability of the modular rigid array design to a Type b. application.

The other option is to apply for direct Canadian government support of non-recurring costs for programs where these are attractive production runs that meet the return criteria established for such government support (e.g. the PILP criterion is 20:1 sales over the ensuing five years).

For flexible arrays where RMSD has proven strength, the market accessible to Spar in the near term will be Olympus and the space station. The same strategy as suggested for rigid arrays can be applied to the flexible market. The Spar experience with Olympus, and earlier on Hermes, both of which were leveraged programs, should put RMSD in a strong position to be competitive in the very high power arrays needed for the space station. If solar arrays were not to be part of the Canadian government contribution to space station, RMSD may still be able to tap this market by applying its flexible array experience in open competition, or by combining forces in some way with a U.S. company. Politics may prevent such independent action by Spar, particularly if NASA places limits on total foreign involvement in the program.

We conclude there is no easily identifiable niche for Spar in the solar array marketplace, but there is a workable strategy where RMSD can use its leveraged solar array business to be competitive in the open market. Spar has a high degree of credibility among prime contractors because of its reputation in the space mechanism field including STEMs, Astromasts and, of course the Canadarm. Astro Research is well known and highly respected among most coast prime contractors. These credentials, it would appear, will make it possible for RMSD to move into the rigid array area, even though there is not a tried and proven design.

The principal competition will be from in-house for most primes, but Lockheed, Ball Aerospace and possibly TRW and Europe would be potential competitors on some programs since each has supplied solar arrays to outside contractors. The operational success of Hermes, and the current involvement in Olympus, places RMSD on the list of credible suppliers. Spar's weakness is in the lack of experience in rigid arrays.

4.4 Recommendations

As a result of our findings and conclusions about the solar array marketplace, we believe there is an attractive and attainable market for Spar for both rigid and flexible arrays following the strategies suggested in the foregoing paragraphs. We recommend that:

1. RMSD mount an aggressive marketing and related R and D program directed toward the attainment of a dominant position as a solar array subsystem supplier.

While most of the current opportunities are in North America, the European market should not be overlooked, particularly because of the dominance of flexible arrays as identified in Table 2. European solar array suppliers may appear to have this market tied up, but it is not beyond the realm of possibility that Canada would make further contributions to ESA in future to provide the leverage necessary for another Olympus-type program wherein RMSD can play a significant role.

In order to gain a strong position in the rigid array market, it is absolutely essential that RMSD win either the HS394 or the Leasecraft array program - the only two that are on the immediate horizon.

We were struck by the responsive chord received during our field visits, and the number of leads that were uncovered. It is clear and obvious that an aggressive marketing campaign includes regular visits to the major prime contractors where the RMSD person making the call has in-depth technical as well as marketing expertise. We recommend that:

2. RMSD make regular and continued visits to major prime contractors at the working level within an overall solar array marketing strategy.

It was also clear that there is need for good coordination among marketing visits by separate Spar entities - particularly RMSD, SASD and Astro Research.

Each should be aware of the others' activities and findings. RMSD has a particular closeness with Astro not only because of the use of STEM and Astromast array deployment, but also because of the interest among those visited in Spar's space mechanism capability. Assuming that such mechanisms, being at the component level, are not of paramount interest to RMSD, Astro should be alerted when mechanism opportunities are uncovered by RMSD. We recommend that:

3. RMSD coordinate with SASD and Astro Research its marketing efforts with respect to spacecraft prime contractors.

It was evident from our visits that solar array technology is moving rapidly toward higher efficiencies and thus smaller arrays for the same power (thereby increasing the array power crossover level between rigid and flexible arrays, currently at 6 kw). Gallium arsenide concentrator arrays are on the way, as are further refinements in mechanisms. Large LEO arrays will need to be welded rather than soldered (e.g. Radarsat and space station.) New materials for space use are becoming available. Clearly RMSD must selectively maintain currency to remain in the solar array business, and we recommend that:

4. Anticipated and identified future needs for solar array and related mechanisms needs be the subject of RMSD R and D activities in order that Spar's technology leads the requirements.

The terms of reference called for an analysis of the vertical integration chain which for RMSD means the addition of cell manufacture and mounting, and cell laydown. We explored with each prime contractor whether or not a solar array buy decision in favour of RMSD would be affected by the need for RMSD to procure cells and blankets externally. In all cases we received an unequivocal "no"; their concern is focussed on meeting requirements on time at an acceptable price. If RMSD can be equally or more efficient by purchasing cells and blankets externally, it is of little consequence to the prime. Thus we recommend that:

5. Vertical integration of the solar array activity, including cell manufacture, mounting and blanket laydown, be based solely on internal make/buy considerations because the market appears to be insensitive to such issues.

* * *

APPENDIX 1

STATEMENT OF WORK

MARKET FEASIBILITY STUDY OF DEPLOYABLE SPACECRAFT SOLAR ARRAYS

1. OBJECTIVE

1.1 To test the hypothesis that spacecraft bus suppliers and prime contractors do not need to maintain in-house deployable solar array supply capability, and that such solar arrays can be purchased more efficiently from a separate specialist supplier.

1.2 To determine if there is a niche for RMSD as a specialist supplier of deployable solar arrays in the general power range 2.5 - 25 kw.

2. STATEMENT OF WORK

2.1 Review technical and marketing data available in RMSD to understand future spacecraft programs and general requirements for solar arrays and related mechanisms.

2.2 Conduct a technical evaluation and economic analysis of the solar array system within a spacecraft bus design, development, supply, integration and test program. In concert with Spar management, select a specific example (e.g. L-SAT, HS394, Leasecraft) and conduct an economic "strawman" analysis and model of the solar array vertical integration chain in order to develop sales arguments for a separate specialist solar array supplier.

2.3 Test hypothesis and sales arguments with SASD to establish appropriate technical and economic strategies for US field visits. Repeat and refine as necessary.

2.4 Test technical and economic arguments with Fairchild Space Company; refine strategy as necessary.

2.5 From field interviews with appropriate business and technical decision makers, determine the feasibility of employing a separate solar array supplier as opposed to performing the work in-house. Field visits will be made to selected spacecraft prime contractors and bus suppliers. Establish for such companies the most appropriate make/buy break points in the solar array vertical integration chain, based on technical and economic analyses. The following companies will be visited:

- o General Electric (Valley Forge)
- o Ford Aerospace (Palo Alto)
- o TRW (Los Angeles)
- o Lockheed Missiles and Space Company
- o Rockwell International (Los Angeles)
- o (No more than two other companies that may emerge during the study)

2.6 Identify key technology trends that will impact make or buy decisions, or will impact solar array supplier ability to remain competitive.

2.7 Identify the appropriate make/buy points in the vertical integration chain for RMSD to remain competitive, taking into account the necessary investment stream for R and D, and for capital, as the chain extends.

2.8 From information obtained by Spar, and from the above field visits, assess strengths and weaknesses of the competition and their likely future strategies.

2.9 Prepare a final report including recommendations.

APPENDIX 2

SLIDES USED IN PRESENTATION

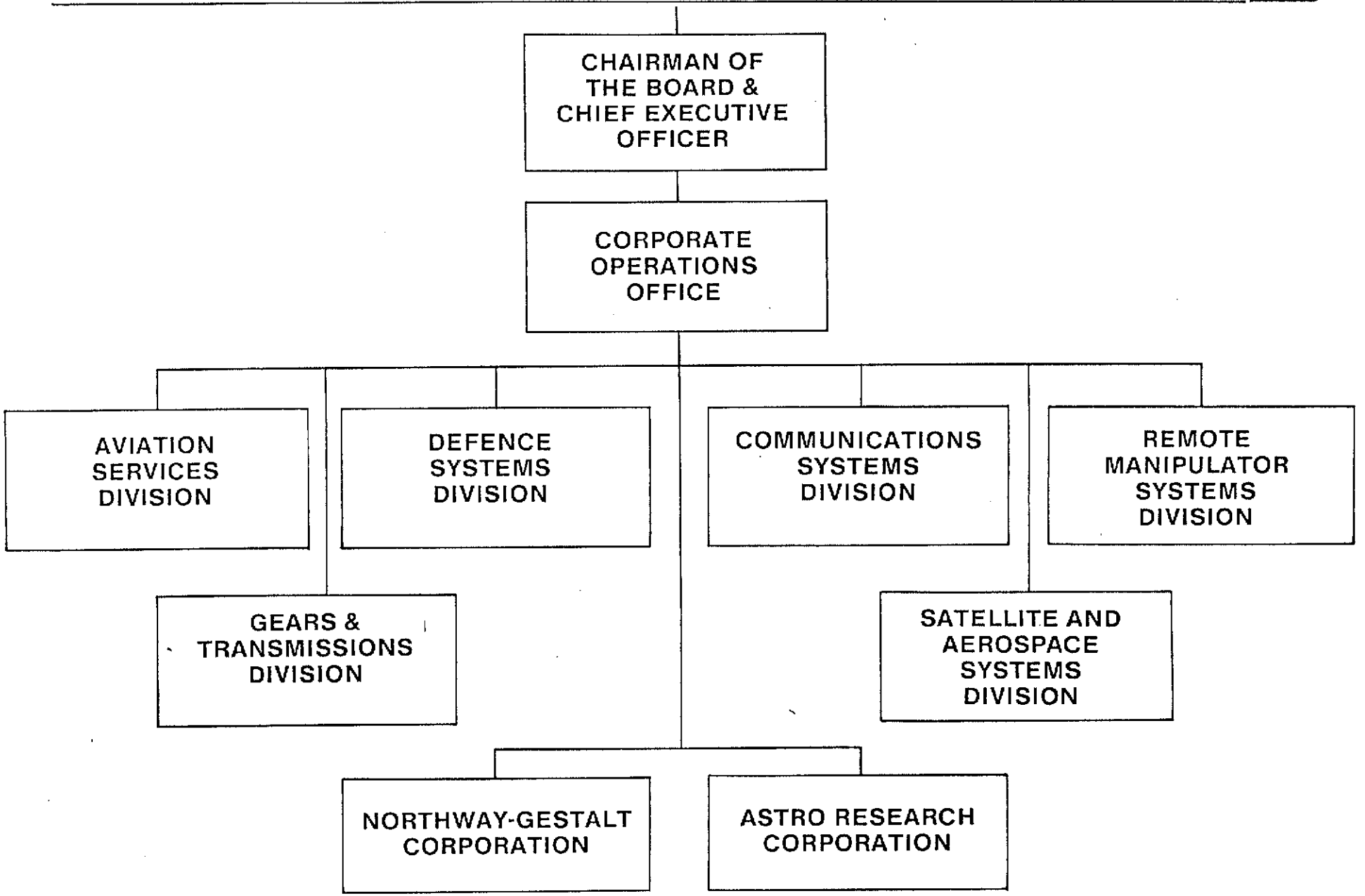
SPAR AEROSPACE

REMOTE MANIPULATOR SYSTEM DIVISION

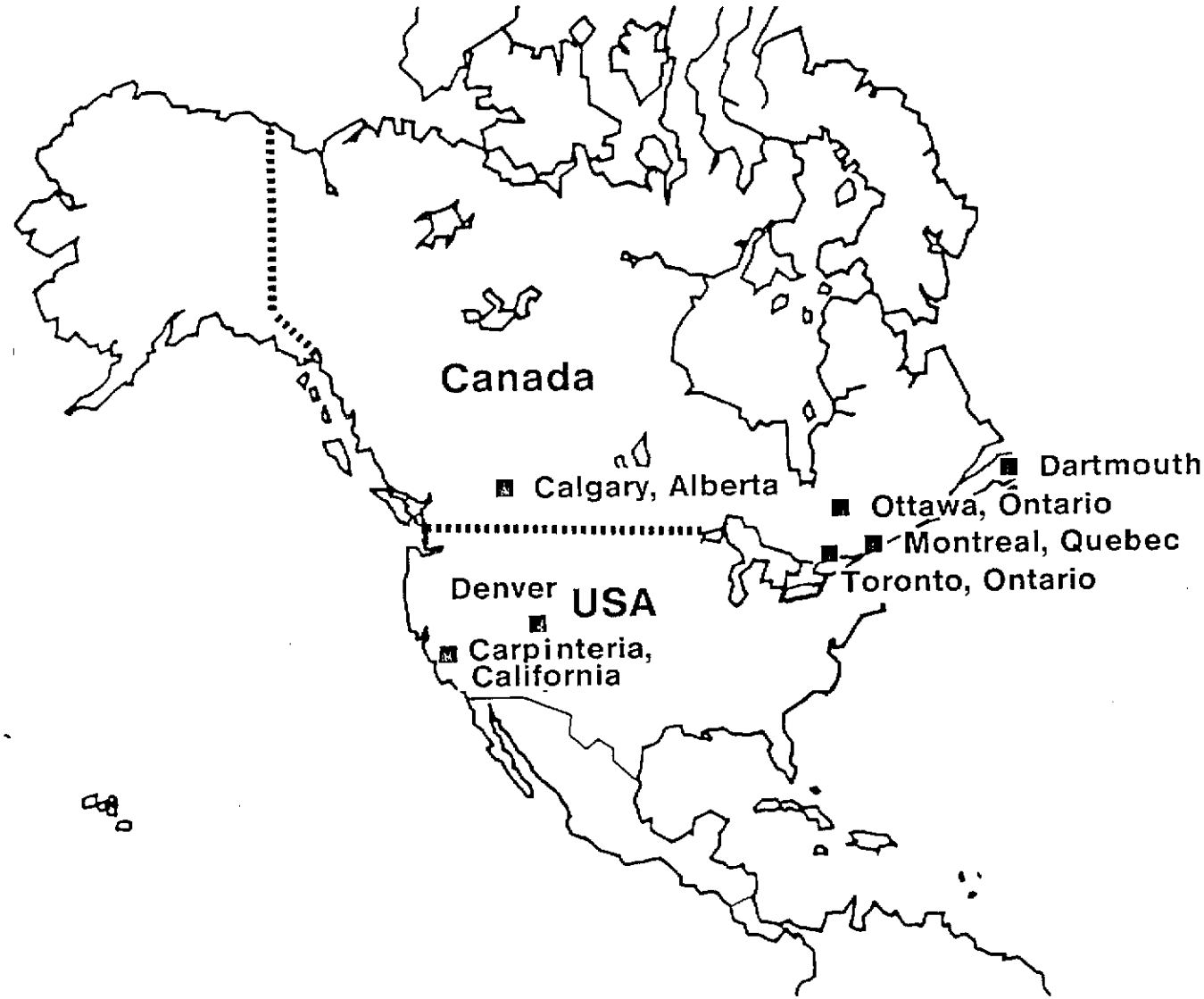
SOLAR ARRAY PRESENTATION

MARCH 1984

SPAR AEROSPACE ORGANIZATION



SPAR AEROSPACE FACILITIES



WHY ARE WE HERE?

SPAR

TO DEMONSTRATE THAT SPAR SOLAR ARRAY CAPABILITY CAN BE VALUABLE TO YOU

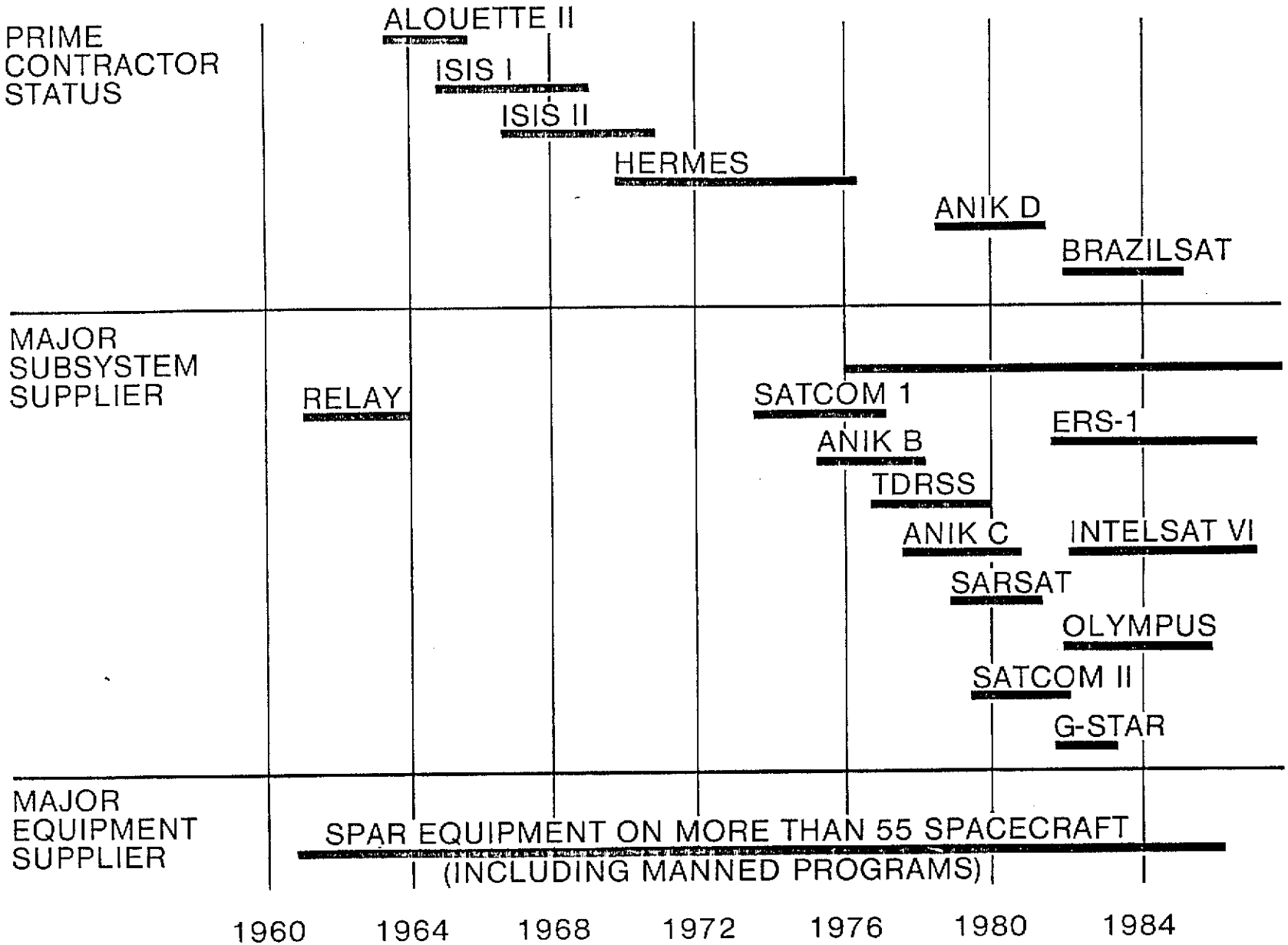
OBJECTIVES

SPAR

- TO PRESENT SPAR AS A PROVEN SOLAR ARRAY SUBSYSTEM SUPPLIER
- TO DETERMINE YOUR CONCERNS ABOUT SOLAR ARRAYS AND FACTORS WHICH WOULD AFFECT DOING BUSINESS WITH SPAR
- TO DETERMINE PRACTICABLE OPTIONS FOR COLLABORATION

SPAR HISTORY IN SPACE

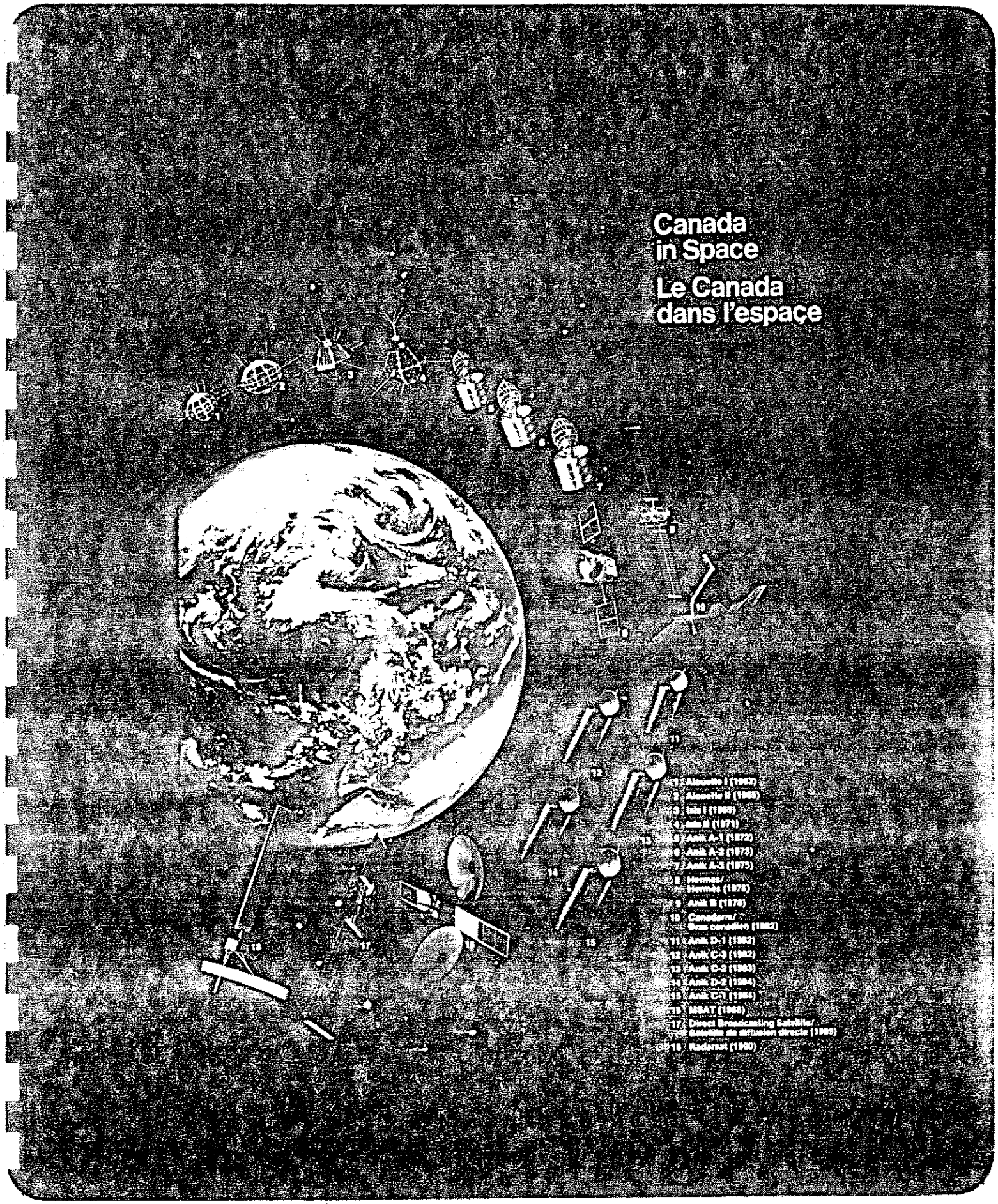
SPAR



SPAR'S 'SPACE' CUSTOMERS

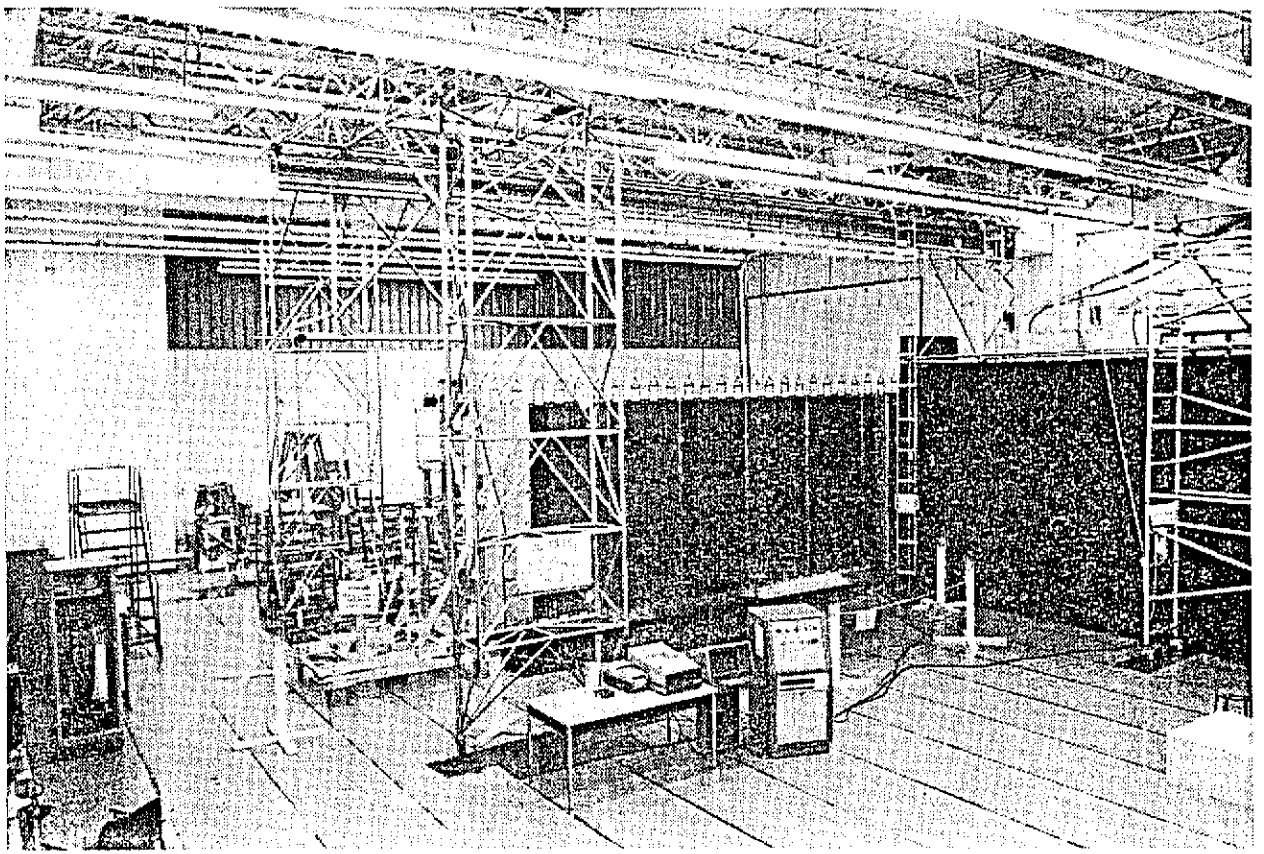
SPAR

CANDIAN GOVERNMENT	U.S. GOVERNMENT	U.S. INDUSTRY	FOREIGN AGENCIES
NRCC DOC EMR DND TELESAT TELEGLOBE	NASA - HQ - JSC - MSFC - GSFC - LERC - LARC - JPL APL NRL AEROSPACE CORP.	TRW HUGHES ROCKWELL LOCKHEED (LMSC) RCA GENERAL ELECTRIC MARTIN MARIETTA McDONNELL DOUGLAS NORTHROP BELL LABS FORD AEROSPACE GENERAL DYNAMICS BOEING BALL AEROSPACE GRUMMAN COMSAT INTELSAT	ESA/ESTEC CNES BRITISH AEROSPACE AEG TELEFUNKEN MSDS (MARCONI) SELENIA LABEN HITACHI TOSHIBA MITSUBISHI ELECTRIC BRAZIL


Canada
in Space
Le Canada
dans l'espace
1 Alouette I (1962)
2 Alouette II (1965)
3 Isis I (1969)
4 Isis II (1971)
5 Anik A-1 (1972)
6 Anik A-2 (1973)
7 Anik A-3 (1975)
8 Hermes/
Hermes (1976)
9 Anik B (1978)
10 Cassiopé/
Symphonie (1982)
11 Anik D-1 (1982)
12 Anik C-3 (1982)
13 Anik C-2 (1983)
14 Anik D-2 (1984)
15 Anik C-1 (1984)
16 MSAT (1988)
17 Direct Broadcasting Satellite/
Satellite de diffusion directe (1989)
18 Radarsat (1990)

THE OLYMPUS SOLAR ARRAY

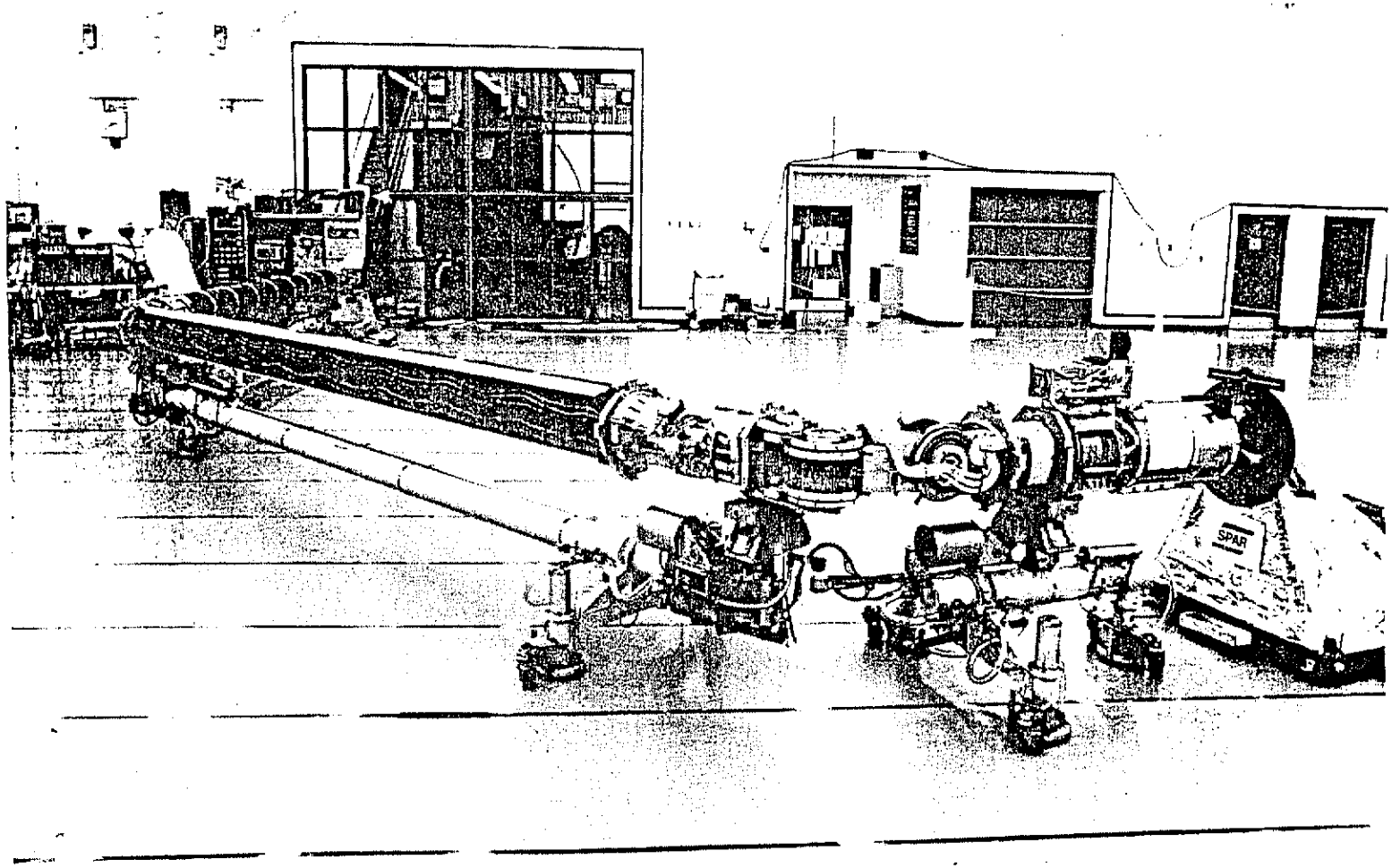
SPAR



- ARRAY PRIME CONTRACTOR
- SYSTEMS ENGINEERING
- INTEGRATION AND TEST
- MECHANISMS
- LAUNCH: 1986

SPAR's INTEGRATION FACILITIES

SPAR



WHY SELECT SPAR AS A SOLAR ARRAY SUPPLIER?

SPAR

TECHNICAL

- DEMONSTRATED COMPETENCE
- TOTAL SYSTEM CAPABILITY WITH SPECIALIZATION IN SYSTEM DESIGN AND INTEGRATION
- SPECIALISTS IN SPACE MECHANISMS

BUSINESS

- COMPETITIVE PRICING
- SECURE AND RELIABLE SOURCE
- INTERNATIONAL MARKET ADVANTAGES
- POTENTIAL OFFSETS
- FLEXIBLE APPROACH TO CONTRACTING

DISCUSSION AGENDA

SPAR

- CURRENT PRACTICE
- MAKE OR BUY FACTORS
- FUTURE PLANS
- TECHNOLOGY TRENDS
- BUSINESS OPTIONS
- SPECIALIST SUPPLIER ROLE
- NEXT STEP?

APPENDIX 3

LIST OF PERSONS CONTACTED ON FIELD VISITS

1. Fairchild Space Company, Germantown, Md. (March 1/84)

   Martin Titland, Executive Vice President
   Don Borrowbridge, Ass't Program Manager, Leasecraft
   John Nagle, Vice President and Program Manager, Leasecraft
   Tom Berry, Chief Engineer
   Dominic P. Manfre, Director Major Sub-Contracts
   Leo Pessin, Engineering Power
   Dr. Chetty, Power Systems

Of all companies visited, this group was the most senior in the corporate decision-making chain. Titland is corporate in his control span, Nagle and Borrowbridge are programmatic. Others have discipline responsibilities covering several programs (e.g. power systems).

2. Ford Aerospace Communications Company, Palo Alto, Ca. (March 5/84)

   Duncan L. Reynard, Manager, Space Systems Operations (Subcontracts)
   A. J. Gamma, International Subcontract Specialist
   W. R. Baron, Specialist, Power Equipment Engineering
   Dr. Bill Young, Solar Array Mechanical Systems
   Nabesh Totab, Manager, Mechanical Systems Engineering

Space Systems Operations of FACC is a $200-300 M/year operation (1100 people) where Reynard is subcontract manager. He deals corporately with subcontract matters across all programs, but is probably not in the corporate investment decision-making chain. Others at the meeting had discipline responsibility across programs.

3. Lockheed Missiles and Space Corporation, Sunnyvale, Ca. (March 5/84

   Garry Turner, Program Manager, Solar Arrays
   Bob Corbett, Manager, Power Systems
   Mike Manning, SAFE Project Engineer
   George J. Welik, Solar Array Programs, New Systems
   Bill Palmer, Electrical Power Systems, Solar Arrays
   David Molodotzky, Assoc. Engineer, Solar Arrays

LMSC's solar array programs are identified as a business centre under Turner who sees this group as a competitor to RMSD. The group had only one major program - the Shuttle SAFE and VOLT experiments, and Turner was unsure of the group's longevity. Decision making power is totally programmatic, but they could make the decision to team with RMSD (e.g. for SII).

4. TRW Systems Group, Manhatten Beach, Ca. (March 6/84)

Jack Friedenthal, Manager, Federal Systems Division
Robert E. Sharples, Manager, Systems Engineering, FSD
Myron Cantor, Systems Engineer
John A. Evans, Advanced Systems Manager
Alfred Fay, Systems Engineer
Ray Hart, Mechanical and Structural Design
Marshall Cannady, Solar Array Design
Herbert Cohen, Systems Engineer
Abraham Fiul, Systems Engineer, Prel. Design
Gary Hatch, Project Manager

This large group represented a wide cross section of programmatic and discipline areas. Friedenthal, while listed as a division manager, has corporate decision powers, and Sharples from FSD has divisional decision powers. This is perhaps the second most senior group contacted during the study.

5. Rockwell International Corporation, Seal Beach, Ca. (March 6/84)

We visited the Space Operations/Integration and Satellite Systems Division, where we met with:

Harold (Hal) M. Kaysen, Project Manager, Adv. Program (Advanced Surveillance)
Baruch Berman, Engineering Specialist, Elect. Power Syst.
Stan Backovsky, Thermal Systems
Lan Hsu, Power Systems
Sol Bretherton, GPS Engineering
Irving Chen, Power and Propulsion
Dewaine Peebles, Sensor Design
K. S. Kim, Payload Specialist
R. E. Cook, Advanced Surveillance
Ken V. Nichols, Member of Tech. Staff, Shuttle Orbiter Division Space System Group (Downey)
Lewis Livingston, Advanced Orbiter Systems, (Downey)

This group is programmatic in their responsibilities, being concerned mainly with the USAF Space-Based Surveillance System. The two from Downey were from a different division with broader responsibilities re the Shuttle.

6. RCA Astro-Electronics, Princeton, N.J. (April 3, 1984)

Chuck Doherty, RCA Marketing
John Brennan, Subcontract Administration
Roger Mancuso, Man., Power/Thermal Systems
Derek Binge, Man., Mechanisms

This was perhaps the most junior group contacted. Brennan did have across-program responsibilities, whereas Mancuso, who escorted us through their solar array fabrication facility, and Binge had discipline area decision powers.