SPAR-R.932 **ISSUE** A

JOINT SPAR/DOC STS/ARIANE LAUNCH VEHICLE STUDY REPORT

VOLUME II

LAUNCH SYSTEM COST ESTIMATES, RISK ASSESSMENT AND COMPARISON

SPAR

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LAUNCH VEHICLE STUDY REPORT

VOLUME II

LAUNCH SYSTEM COST ESTIMATES,
RISK ASSESSMENT AND COMPARISON

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TABLE OF CONTENTS

Section	Title	Page
1.0	INTRODUCTION	1-1
2.0	COST ASSESSMENT	2-1
	2.1 Space Transportation System/MDAC Payload Assist Module-Delta	2-1
	2.1.1 STS Basic Charge - 1975 U.S. $	2-2
	2.1.2 STS Optional Charges - 1975 U.S.	2-4
	2.1.3 Custom Charges	2-6
	2.1.4 Total STS Charges	2-6
	2.1.5 PAM-D and ASE Charges	2-6
	2.1.6 Total STS/PAM Charges	2-10
	2.2 Ariane Launch System	2-10
3.0	STS/PAM-D VERSUS ARIANE COMPARISON	3-1
4.0	CONCLUSIONS	4-1

LIST OF TABLE

Table	Title	Page
2.1-1	OPTIONAL STS CHARGES	2-5
2.1-2	STS PRICING SUMMARY	2-7
2.1-3	MUSAT CONFIGURATION A, EXPECTED PAM CHARGES	2-8
2.1-4	PAM-D PRICING SUMMARY	2-9
2.1-5	TOTAL STS/PAM CHARGES	2-9
2.2-1	ARIANE PRICING SUMMARY	2-11

LIST OF FIGURES

Figure	Title	Page
3.1-1	SPACECRAFT ENVELOPE CONSTRAINTS	3-3
3.1-2	ARIANE/STS COST BUILD-UP	3-16

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1.0 INTRODUCTION

This volume of the STS/Ariane launch vehicle study report assesses the costs for the STS and Ariane launch vehicles and services using the Canadian MUSAT spacecraft as the model. To do this, the cost policies and data, plus the responsibilities presented in Volume I are applied.

No effort has been made to define the user manpower charges required to interface with the launch vehicle operator and conduct the launch campaign. Only those which could be materially different between Ariane and STS have been addressed.

Also contained in this volume is a comparison matrix between the two launch systems, which includes a risk assessment.

2.0 COST ASSESSMENT

Many of the cost figures presented in Volume I are specified for a given point in time. These values must be inflated to today's dollars and beyond. According to the United States Bureau of Statistics, the inflation rate of 28.6% from January 1, 1975 to January 1, 1978 is applicable. Thereafter, the U.S. government is applying a rate of 7.0% per annum. These values will also be used for this cost evaluation.

Of course, the present trend in the decline of the U.S. currency on world markets plus the uncertainty of STS charges for launches occurring after the first three years of operations (i.e. subsequent to June, 1983) could substantially affect the ultimate cost tradeoff between Ariane and the STS. The basic policy of ESA remains that they will endeavour to maintain a price for a Delta class launch (i.e. tandem with SYLDA) which is competitive with the STS/SSUS-D vertical launch charges.

A launch date of October 1, 1982 has been assumed for the first MUSAT spacecraft.

2.1 Space Transportation System/MDAC Payload Assist Module-Delta

The following assumptions have been made regarding the MUSAT payload requirements on the launch vehicle.

(a) Injection will be from the standard STS ETR parking orbit, 160 nmi altitude, circular at 28.5 degrees inclination, during the operational phase of the STS when the load capacity will be 65,000 lbs. in this orbit.

(b) A nominal prelaunch schedule of 25 days off-line and 10 days on-line at KSC (no extra NASA charges for extended ETR activities).

(c) During launch operations (after lift off) the spacecraft will be controlled from the central control station (CCS) in Canada, via the POCC at GSFC prior to deployment from the orbiter, and directly or via a transportable tracking station thereafter. Additional charges are therefore applicable for ground link communications to Canada, voice and data from POCC and voice from ETR.

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(d) The first stage of flex-PAM capability will be required, capacity of 2550 lbs. separation weight.

(e) The PAM-D spacecraft sun shield will be required.

(f) One additional dynamic load analysis will be required from either JSC/RI or MDAC during the early design phase. Also, the prime contractor will acquire the cargo dynamic and thermal computer models for user confirmation analysis.

(g) MUSAT, with its commercial payload segment, does not qualify for the U.S. Civil Government rates and Canada must pay use fees.

(h) MUSAT is 3-axis stabilized without need for active nutation control except during free flight with the PAM. The spacecraft will, however, provide this function to save weight and money.

2.1.1 <u>STS Basic Charge - 1975 U.S. $</u>

Here two possible MUSAT configurations are considered, reference Appendix A, Volume I of this report:

3MCLA154.7

(a) As a baseline, assume a configuration A that stows vertically in the orbiter bay (101 inch spacecraft height maximum) and fits the 86 inch Delta shroud diameter. Configuration A, therefore, utilizes 86 + 6 inch mandatory forward + aft clearance = 92" of orbiter length.

The total weight in the orbiter bay is 2247 lbs. (ASE) plus 50 lbs. (spacecraft sun shield) plus 2500 lbs. (spacecraft) plus 4380 lbs. PAM-D = 9177 lbs.

Per JSC-11802, for Configuration A:

$$\text{Load Factor} = \frac{9,177}{65,000} = \underline{.141} \text{ by weight}$$

$$= \frac{92}{720} = .128 \text{ by length}$$

$$\text{Charge Factor (Cf)} = \frac{.141}{.75} = \underline{.188}$$

(b) As an alternate, assume a configuration B, per the CRC concept drawing M-10760 sheet 1, which is 161.2 inches in length from the spacecraft separation plane to the tip of the log spiral cone UHF feed. This spacecraft would be mounted horizontally in the orbiter bay with a PAM-A (Atlas Centaur) cradle. Mr. P. Peterson, MDAC, indicated that the PAM-A cradle length from the back of the spin motor to the spacecraft separation plane is 92 inches for a PAM-D application and that if an elevation of 35° is required for deployment an additional 2 inches of aft motion of the spin motor and 1 inch forward motion of the payload can be expected.

The total payload length would then be:

1 + 161.2 + 92 + 2 + 6 inch forward + aft clearance = 262.2 inches in the orbiter.

The PAM-A Airborne Support Equipment (ASE) weight for a PAM-D launch weighs 3800 lbs. plus a spacecraft sun shield of 100 lbs. = 3900 lbs. With a PAM-D weight of 4380 lbs. (including attach fitting) for a MUSAT separation weight of 2500 lbs. the total weight in the orbiter bay is 10,780 lbs.

Per JSC-11802, for Configuration B:

$$\text{Load Factor} = \frac{10,780}{65,000} = .166 \text{ by weight}$$

$$= \frac{262.2}{720.0} = \underline{.364} \text{ by length}$$

$$\text{Charge Factor (Cf)} = \frac{.364}{.75} = \underline{.486}$$

The basic charges (standard services) for the STS for MUSAT are therefore calculated to be:

Configuration	Charge			
	Transportation*	Reflight* Guarantee	Use+	Total
A	3.384	0.051	0.808	4.243
B	8.748	0.132	2.089	10.968

in millions of U.S. dollars, January, 1975.

* Subject to escalation
\+ Fixed

2.1.2 STS Optional Charges - 1975 U.S.

Table 2.1-1 is a list of optional charges which are expected to be required for MUSAT and which would be contracted at program start.

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TABLE 2.1-1

OPTIONAL STS CHARGES

Charge Category	Charges $K, U.S. 1975 (January) Subject to Escalation	Not Subject to Escalation
1. KSC		
- Interfacility communications	12.5	
- Scape suits	1.0	
- Safety monitoring	16.3	
- Launch site support management, non-recurring	120.0	
- Launch site support management, recurring	33.8	
- Propellant handling	0.4	
- Others	0.5	
- Overhead (desks, security, etc.)	23.6	
- AKM motor storage (6 months)	1.3	
- Payload processing facility PPF and DSTF*	33.2	25.2
- Clean room at PPF (estimate)	30.0	25.0
- Communications KSC to Ottawa+	16.3	
Subtotal	288.9	50.2
2. Communications JSC to Ottawa+	16.3	
3. Use of POCC (unknown)	40++	30++
4. Parasitic Antenna at KSC (unknown)	20++	
5. Additional Front End Dynamic Loads Analysis (1 cycle) (JSC)	70.0	
6. Spacecraft Uplink Commands Through STS T&C from Ground	65.0	
TOTAL	$500.2K	$80.2K

* 25 day program assumed for PPF and DSTF
\+ 3 month period assumed
++ Guesstimates

2.1.3 Custom Charges

None have been identified for MUSAT. However, with the schedule of Figure 2.1-1, late signup charges might well apply. Also, no late spacecraft availability contingency funds have been allotted.

2.1.4 Total STS Charges

In summary, the total STS charges for MUSAT, in January, 1975, US.S. $M, are expected to be as follows:

Charge Categories	MUSAT Configuration A	MUSAT Configuration B
1. Subject to escalation:		
- basic transportation	3.384	8.748
- reflight guarantee	0.051	0.132
- optional services	0.500	0.500
Subtotal	3.935	9.380
2. Fixed:		
- basic use charge	0.808	2.089
- optional facilities	0.080	0.080
Subtotal	0.888	2.169
3. Total	$4.823M	$11.549M

The charges, have then been computed in real year dollars are as shown in Table 2.1-2.

2.1.5 PAM-D and ASE Charges

The charges for the PAM-D launched in a PAM-A cradle were not available in time for this report. It is therefore assumed that they are equivalent to those for a vertical PAM-D configuration except

TABLE 2.1-2

STS PRICING SUMMARY

			Escalated Portion of Payment				
Months Before Launch	Payment Due Date	Percent of Total Due	1975$	Real-Year$	Escalation Factor	Non-Escalated Portion of Payment	Projected Total Escalated Payment
Conf.A							
36	Oct./79	0	0.100	0.145	1.45	0.000	0.145
33	Jan./80	10	0.283	0.416	1.47	0.089	0.652
27	July/80	10	0.394	0.599	1.52	0.089	0.688
21	Jan./81	17	0.669	1.057	1.58	0.151	1.208
15	July/81	17	0.669	1.091	1.63	0.151	1.290
9	Jan./82	23	0.905	1.529	1.69	0.204	1.733
3	July/82	23	0.905	1.575	1.74	0.204	1.779
TOTALS		100%	$3.935M	$6.412M		$0.888M	$7.300M
Conf.B							
36		0	0.100	0.145	1.45	0.000	0.145
33		10	0.838	1.232	1.47	0.216	1.448
27		10	0.938	1.426	1.52	0.217	1.643
21		17	1.595	2.520	1.58	0.369	2.889
15		17	1.595	2.600	1.63	0.369	2.969
9		23	2.157	3.645	1.69	0.499	4.144
3		23	2.157	3.753	1.74	0.499	4.252
TOTALS		100%	$9.380M	15.321M		$2.169M	$17,490M

NOTE: Excludes PAM charge.

for the optional sun shield. In reality, although the charges for the use of the ASE may be the same in the two cases, there are likely to be additional, yet unaccounted for, operational charges for the rotation of the spacecraft prior to deployment. MDAC have not fully analyzed and priced the longitudinally oriented Delta class payload SSUS. The charges for MUSAT Configuration A are as shown in Table 2.1-3.

TABLE 2.1-3

MUSAT CONFIGURATION A, EXPECTED PAM CHARGES

Charge Classification		Charge (Jan. 1980 U.S. $M)
1. Standard		2.1
2. Mission Specific:		
- Initial mission package	0.800	
- Provision of dynamic models	0.015	
- Spacecraft sunshield	0.050	
- Attach fitting, marmon clamps, etc.	0.070	
- $ Buffer recommended by MDAC	0.500	
Subtotal		1.435
3. Incremental Performance		0.150
TOTAL CHARGES		$3.685M

For Configuration B add .050M$ for additional sun shield charges.

The MDAC PAM-D charges, computed in real year dollars, based upon the assumed MUSAT schedule, Figure 2.1-1, are as shown in Table 2.1-4.

TABLE 2.1-4

PAM-D PRICING SUMMARY

Months Before Launch	Payment Due Date	Percent of Total Due	January, 1980 $M	Real-Year $M (Estimate)	Escal-ation Factor
Upon Agree-ment	(Apr.1/80)	2	0.074	0.075	1.017
30	Apr./80	10	0.369	0.375	1.017
27	July/80	7	0.258	0.267	1.034
24	Oct./80	7	0.258	0.271	1.052
21	Jan./81	7	0.258	0.276	1.070
18	Apr./81	7	0.258	0.281	1.088
15	July/81	7	0.258	0.286	1.107
12	Oct./81	7	0.258	0.291	1.126
9	Jan./82	17	0.626	0.717	1.145
6	Apr./82	17	0.626	0.729	1.164
3	July/82	6	0.221	0.262	1.184
Launch	Oct./82	6	0.221	0.266	1.205
TOTALS	(Config. A)	100%	$3.685M	$4.096M	
TOTALS	(Config. B)		$3.735M	$4.152M	

TABLE 2.1-5

TOTAL STS/PAM CHARGES

	Charges in Oct./82 $M		
	STS	PAM-D	Total
Configuration A	7.300	4.096	$11.396M
Configuration B	17.490	4.152	$21.642M

2.1.6 Total STS/PAM Charges

The total charges, not including user/contractor manpower and equipment, for the STS/PAM launch services is expected to be $11.396M U.S., then year, for MUSAT Configuration A and $21.642M U.S., then year for Configuration B as shown in Table 2.1-5. Of course, this differential would be a major driver in the design of MUSAT to meet a configuration which can utilize a minimum of orbiter bay length.

2.2 Ariane Launch System

The cost to the user for the Ariane launcher utilization is relatively straightforward. For a dedicated launch, the costs are $22 million U.S. in mid-1977. The costs should be escalated by an inflation factor for each year. These costs include the provision of the standard launch support services at the launch site. Optional services include the use of a spin up system to increase the spacecraft spin rate from 10 rpm to 60 rpm and the use of the ESA tracking network for the satellite which ESA will quote on only after the network requirements are specified by the User in some detail. Added to the launcher and launch services costs, is a re-launch guarantee if the first launch fails due to a fault of the launch vehicle. This could be a maximum of 10% of the launch costs.

In the case of a dual (SYLDA) launch, the mid-1977 costs for each satellite are quoted at $15 million U.S. For the MUSAT model utilized in this launch cost study, if we assume a dual launch in October, 1982, the payment schedule would be as shown in Table 2.2-1.

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TABLE 2.2-1

ARIANE PRICING SUMMARY

Month Before Launch	Payment Due Date	Per-cent of Total	July/77 $M	Real-Year $M (Estimate)	Escalation Factor - 7%	Re-Launch Guaran-tee 10%
30	Apr/80	10	1.500	1.807	1.2045	.181
24	Oct/80	10	1.500	1.869	1.2459	.187
18	Apr/81	25	3.750	4.833	1.2888	.483
12	Oct/81	25	3.750	4.999	1.3331	.500
6	Apr/82	20	3.000	4.137	1.3790	.414
0	Oct/82	10	1.500	2.140	1.4265	.214
TOTALS		100%	$15.000	$19.785		$1.979

Notes:
1. Base Price $15 million U.S. in mid-1977
2. Assumed escalation of 7% per year due to inflation.
3. Charges for spin table not included
4. Charges for Communications Link between Kourou and Canada $K50 not included

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3.0 STS/PAM-D VERSUS ARIANE COMPARISON

This section of the report presents a summary comparison matrix betwen the STS/PAM-D launch system and the Ariane launcher, as they are presently configured and priced for a Delta class payload. The launchers' environments and detailed technical interfaces are not discussed in the context of this report.

Point of Comparison	STS/PAM-D	Ariane	Comments
Length and Volume (see Figure 3.1-1)	Allows up to 15' x 60' cargo space. For cost effective launch, spacecraft cannot be 101" high (from separation plane) and AKM axis must be aligned with orbiter Z axis.	With dedicated launch spacecraft maximum length = 293" and diameter = 118. However, with SYLDA for cost effective Delta class launch, axial length = 101" and diameter = 86" with a potential axial length = 165" and 118" diameter for the top rider.	Equivalent length and diameter for cost effective Delta launch.
Weight	Separation weight from PAM-D is 2320 lbs into 27° geosynchronous transfer orbit (can increase to 2750 lbs with extra $ (i.e. 1500 lbs after AKM fire). Centaur class (PAM-A) capable of 4400 lbs to the same orbit (i.e. 2400 lbs after AKM fire)	For dedicated launch, maximum weight at separation into 9.5° geosynchronous transfer orbit is 3856 lbs (i.e. 2250 lbs after AKM fire). For tandem launch top rider can weigh up to 2645 lbs (i.e. 1545 lbs after AKM fire).	Ariane takes advantage of the low inclination launch site location to provide equivalent Delta class weight carrying capability to STS/PAM-D at completion of AKM fire. Smaller resulting AKM allows greater growth potential for future LV enhancements while still retaining presently existing AKM hardware.

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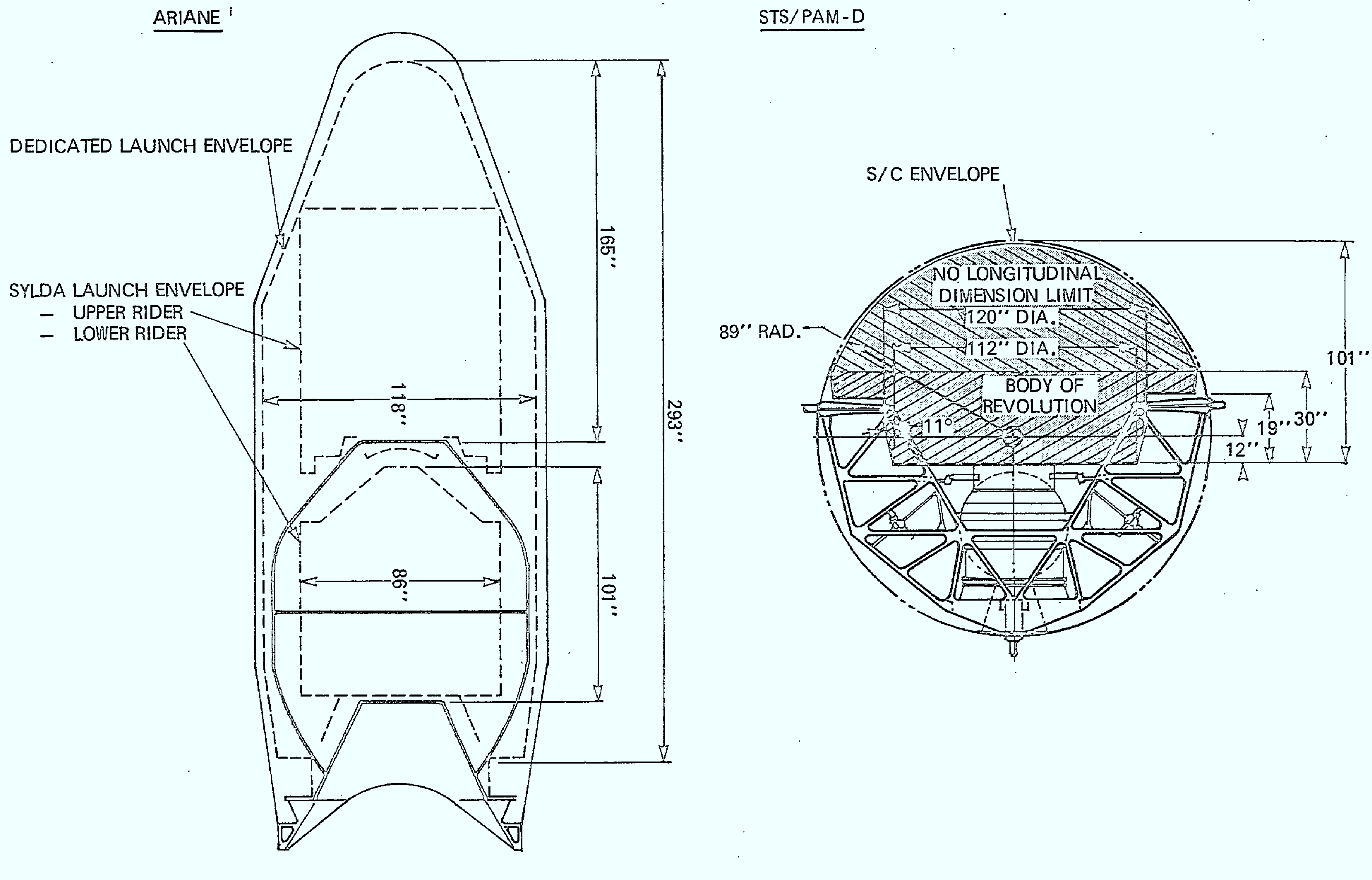

FIG. 3.1-1 SPACECRAFT ENVELOPE CONSTRAINTS

Point of Comparison	STS/PAM-D	Ariane	Comments
Attitude Pointing at Separation	PAM-D relies on active nutation control (ANC) supplied either by the spacecraft or the PAM to maintain adequate pointing during 45 minute coast from the orbiter and prior to PAM ignition. Spacecraft spin axis nominally aligned along trajectory vector except for tip-offs.	Ariane has sophisticated on-board attitude control system that can orient the payload in any direction desired prior to spinup and separation. For tandem launch, both payloads must have the same orientation.	With Ariane, the major manoeuvre of reorientation into AKM firing attitude and preferred sun angles can be performed by the launcher thereby saving approximately 7 lbs of RCS fuel (Delta class) and minimizing hazardous operations in the transfer orbit. Also, with STS/PAM if spacecraft ANC utilized, User has joint responsibility i.e. significant user analyses.
Spin rate	0-100 rpm with high accuracy and adjustment in-flight.	10 rpm maximum	Spin rate too low with Ariane for accurate AKM fire. Spinup required beforehand

Point of Comparison	STS/PAM-D	Ariane	Comments
Transfer Orbit Parameter Dispersions	Because of long drift, Dispersions are relatively high, ha = ±440 NMI hp = ± i = ±0.63°	Because of sophisticated real time, on-board computation of state vector and correction of trajectory and cutoff, dispersions are very low, ha = ± 23.3 NMI hp = ± 0.24 NMI i = ± 0.019°	RCS fuel required for station acquisition, 3σ dispersions, will be significantly lower with Ariane
Risk Assessment			
1. Launch Flight Failure	Due to manned rating, probability of failure less than with ELV. Also, payload can be retrieved in event of a post-launch STS abort. Capability of spacecraft checkout in-orbit while still in the orbiter bay allows spacecraft abort and recycle	Conventional ELV, sequenced and committed from lift-off. High level of redundancy, where possible, and reuse of proven technology in this vehicle. More conservative and thorough program than previous European launchers.	Additional STS reliability/flexibility comes at a price. User must plan and design potential abort and for in-orbiter checkout if desired. Also condition of payload after re-entry is suspect due to ambient air ingress, hot thermal soaking, especially if not

Point of Comparison	STS/PAM-D	Ariane	Comments
Risk Assessment			
1. Launch Flight Failure (cont'd)			landing at ETR, and landing loads. Further, spacecraft may have to be disposed of in-orbit if a spacecraft failure causes a hazard to crew safety. Complicated in-orbit checkout with STS may require extra time (@300-350K per day, 1975 $ U.S.) and direct T&C access. Difficult to assess overall launcher deliverabilities until they have flown several times.

Point of Comparison	STS/PAM-D	Ariane	Comments
Risk Assessment			
2. Launcher Availability - First Flight	The STS First Manned Orbiter Flight has been officially slipped to June, 1979 due to problems with main engine turbo pumps and time required for thermal surface application. Further slips to 4th quarter, 1979 are likely. Eventual operability of the system in time for MUSAT (1982) is unquestioned. STS delays may advance earnest money payment for MUSAT if flight demand concentrated in the early 1980s. The U.S. military has priority over any other payload and user may get bumped at any time up to launch. NASA has scheduled 2-3 launch aborts per year which are fillers and should absorb any such military interventions. However, user must be prepared to recycle for up to 3 months delay.	The first LO1 flight is still on target for June, 1979, with a throat insert degradation problem on the 1st stage engine presently posing the only threat for delay. A 95% confidence level, is shown by ESA, that this problem will be resolved with a change of materials to phenolic-resin in time for schedule LO1. Availability of a small European tandem payload which would allow full STS/PAM-D weight capability in advance of Ariane capability upgrading is uncertain.	Ariane is more likely to be launched before STS.

Point of Comparison	STS/PAM-D	Ariane	Comments
Risk Assessment			
3. Spacecraft Problems at the Launch Pad	Because the automated payload may not be the most important passenger, NASA have indicated that if a problem occurs in the freeflyer at a point in the launch sequence that will significantly affect the launch date (i.e. > 3 days), this may result in a launch on schedule, using the freeflyer as a mass simulation for the round trip.	The launch would be delayed until the problem was solved. Costs to the user have not been specified by ESA.	Ariane appears to provide greater launch delay flexibility on the pad, even in the case of the tandem launch

Point of Comparison	STS/PAM-D	Ariane	Comments
Risk Assessment			
4. Confirmation of Spacecraft Separation	The PAM-D telemetry system is out of range (35-40 miles) of the orbiter S-band receiver at spacecraft separation. No confirmation.	Confirmation by Ascension Island STDN station, 10 minute delay in receipt of data at CSG. With SYLDA, separation of inner rider just barely within range by seconds. May require transportable station on the Ivory Coast.	Positive indication of spacecraft separation can be important from an insurance /contractual sense as well as from a technical reassurance standpoint
Launch Site Operations			
1. Facilities	All facilities at ETR will be adequate for payload checkout, hazardous operations and launch. However, potential bottlenecks include DSTF with 1 spin machine, which will need to process 40 payloads per year (present 26 maximum). Payload off-line pro-	All facilities at CSG will be adequate for payload checkout, hazardous operations and launch. Lower launch rates should allow greater flexibility in launch vehicle scheduling.	Both facilities adequate with CSG less likely to impose unexpected schedule constraints

Point of Comparison	STS/PAM-D	Ariane	Comments
Launch Site Operations			
1. Facilities (cont'd)	cessing will have to be more efficient while at the same time being thorough to ensure that the payload does not subsequently delay the critical and costly STS on-line schedule.		
2. Environment	Weather generally fair, without pronounced rainy season.	Temperature 20-34°C. Relative humidity generally 90%. Rainy season December to July (up to 4.5 metres/yr). Air conditioning required for the payload during transport, in processing facilities and on the launch vehicle.	Extra precautions required at CSG but should not affect P/L safety or reliability. Personnel recommended to have Yellow fever, Smallpox, Hepatitis immunization
3. Personnel Accommodations	Adequate accommodation (and recreation) facilities in the Cocoa Beach/ Orlando area.	Adequate accommodation will be available for launch team in Kourou. Recreation facilities less diverse than Florida but more exotic	Adequate - both sites

Point of Comparison	STS/PAM-D	Ariane	Comments
Launch Site Operations			
4. Communications	RF communications directly with the spacecraft while in the orbiter at the pad are not presently available to User equipment located in off-line processing facilities. Only T-O umbilical data available in these locations. When connected to orbiter (interleaved data bus) data available at LCC (ETR) and POCC (JSC and GSFC). Land lines can be rented from there to Canada. Possibility of setting up a parasitic antenna for the pad operations is now under investigation by NASA. Voice and personnel/material transport communications are relatively quick and good quality.	Commercial transport (personnel and materials) to Kourou from North America is presently slow with stopovers required in the Carribean. Recommend charter aircraft availability Canada or Florida to Kourou on standby (retainer) throughout the launch site campaign. Voice communications, commercial non-dedicated, to Canada can also be slow and is expensive ($8.40 per minute). Dedicated data and voice communications channels must be rented at up to 50K$ for a 3 month period. Capability for RF communication around the CSG facility will be available on the launcher, provided that the RF window in the shroud is positioned to allow this	It is, naturally more convenient to travel within North America rather than to South America. Extra charges for the latter will be incurred to provide reasonable communications. On the other hand, internal communications with the spacecraft on the pad are more convenient at CSG than at ETR.

Point of Comparison	STS/PAM-D	Ariane	Comments
Mixed Cargo Interface/ Manifesting	Operator responsibility complicated by the 3rd stage carrier agency and integrator for on-line processing. Manifest not complete until 18 months before launch. Potentially very complex and constraining fellow passengers (eg: Spacelab).	Operator responsibility, manifest established during feasibility studies 30 months before launch.	Even with tandem launch, the interfacing for conventional payloads should be simpler with Ariane and more timely in the program.
Flight Operations	-Diverse high priority missions may constrain automated payload to more than 1 day in the orbiter bay, making mission analysis a more complex task. Severe thermal environments (30 minutes sun, 90 minutes cold space and earth pointing indefinitely) require addition of sun shields for spacecraft protection while in the bay. -Flexibility, in-flight, to change the timeline. -Direct RF communications with the payload from a	Conventional ELV, no in-flight flexibility. Straightforward timeline and environments.	STS flexibility versus mission and spacecraft design complexity tradeoff. By the time of MUSAT (1982) the geosynchronous mission should be standardized.

Point of Comparison	STS/PAM-D	Ariane	Comments
Flight Operations (cont'd)	ground station while in the bay may not be possible. -Launch window constrained to 30 minutes after sunrise to 30 minutes before sunset.		
Analysis Responsibility	Operator/3rd stage carrier responsible for combined cargo analyses (except for stability during drift prior to PAM fire if spacecraft ANC utilized). Many are optional charges. Additional cycles for design purposes can be purchased. STS operator only concerned for STS hardware and personnel safety so their analyses for cargo compatibility verification are late in the program, 12-6 months before launch.	Operator responsible for all combined cargo analyses (structural, thermal, RFI, EMI, mass properties, mech. interface, mission). First cycle performed in time for utilization during payload design phase.	Ariane should provide more timely combined analyses for the User under the basic charge. User less able to perform combined analyses himself for the complex STS LV.

Point of Comparison	STS/PAM-D	Ariane	Comments
Schedule	The STS program will typically start 36 months before launch with a User earnest money payment at that time. The launch campaign at ETR will be a minimum of 25 days off-line and 10 days on-line processing	The Ariane program will typically start 30 months before launch. The launch campaign at CSG will be up to 35 days off line and 7 days on line for a dedicated launch with approximately 3-6 days added for tandem payload stacking	Compatible launch campaigns if all goes well

Milestone Payments		STS/PAM-D Months to Launch	STS/PAM-D %	Ariane Months to Launch	Ariane %	Comments
	STS:	36	Earnest	30	10	STS charges deferred compared to Ariane. Either method could be advantageous depending upon User's financial needs.
		33	10	24	10	
		27	10	18	25	
		21	17	12	25	
		15	17	6	20	
		9	23	0	10	
		3	23			
	PAM-D:	on agreement	2			
		30	10			
		27	7			
		24	7			
		21	7			
		18	7			
		15	7			
		12	7			
		9	17			
		6	17			
		3	6			
		Launch	6			

Point of Comparison	STS/PAM-D	Ariane	Comments
Insurance			
1. User	Expected to be 6% to cover spacecraft replacement, second launch, lost revenues, loss of incentives, etc. in event of spacecraft failure.	Expected to be 10% to cover per STS/PAM-D, at least initially until launcher reliaiblity established.	Significant cost for Ariane since it is not man-rated and not yet flight proven
2. Operator/ Carrier	Operator guarantees reflight, through June, 1983, for $271K U.S., 1975, in event of a launch vehicle failure. Carrier will also guarantee replacement of PAM-D but only at extra cost, not yet specified.	Operator guarantees reflight, in event of a launcher failure, for 10% of the value insured. (Could be approximately $2M).	Significant cost for Ariane since it is not reuseable
Total Cost	A total cost comparison can be derived from Figure 3.1-2 for the MUSAT type, Delta class payload. Not included (Canadian Government self insures) but very significant, is the User's insurance. The STS curves, as a function of payload bay length and weight, are inclusive of the Use fee.		

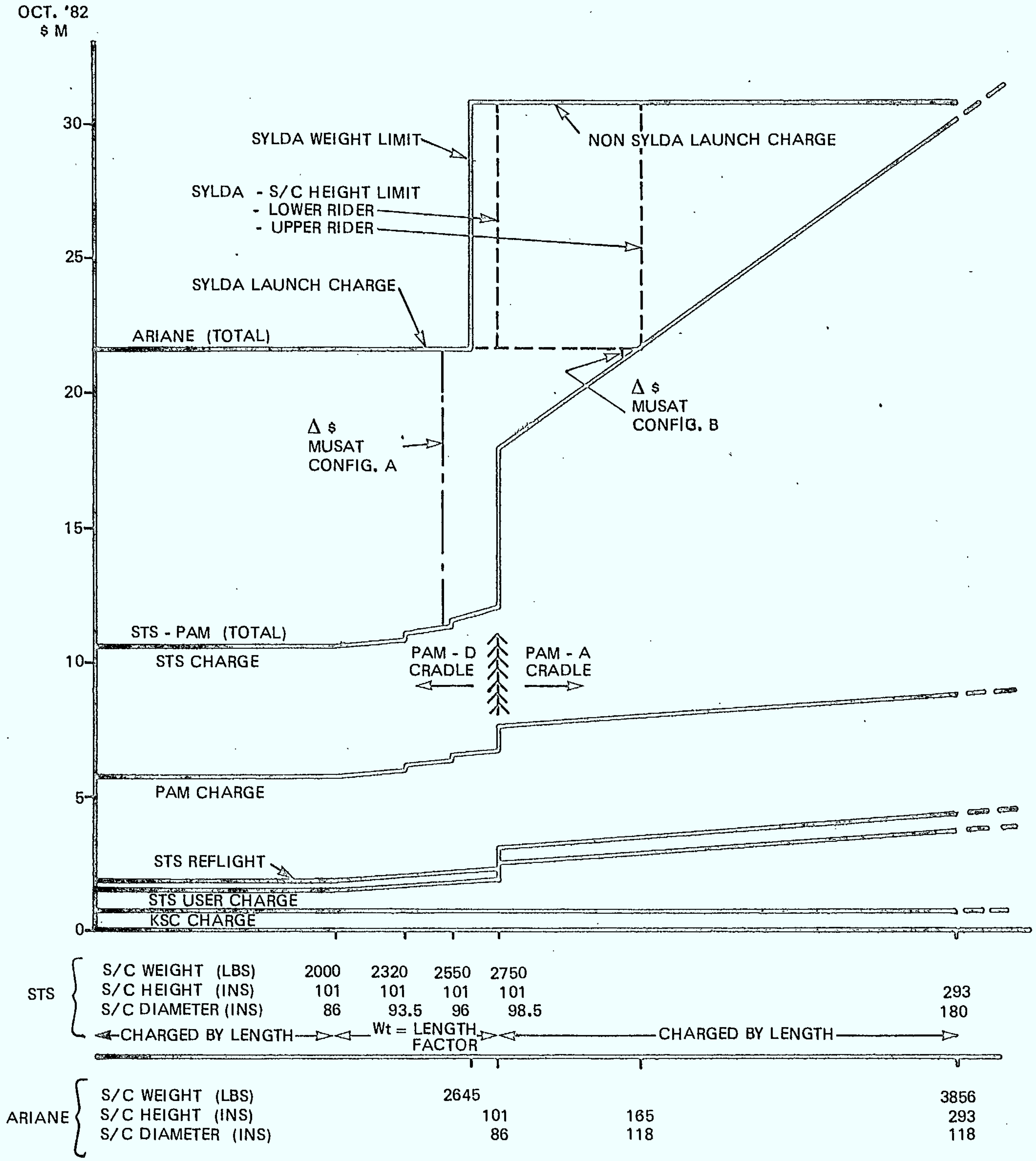

FIG. 3.1-2 ARIANE/STS COST BUILDUP

NOTES FOR FIGURE 3.1-2

1. Use fee included.

2. PAM-A charge unknown and not estimated.

3. User insurance not included.

   eg: MUSAT Configuration B STS $M2.54 U.S., Oct/1982
   Ariane $M4.25 U.S., Oct/1982

4. MDAC 3rd stage PAM only shown. Alternate concepts (eg: SYNCOM 4) could be more shuttle optimized and will have different costs.

4.0 CONCLUSIONS

Both agencies, NASA and ESA, along with their supporting partners, have been open with published and advanced information relative to their launch vehicles. Both have expended significant effort to ensure that this study contains useful and current (as of July, 1978) comparative and informative data.

The STS, with its inherent flexibility, reliability and reuseability offers the User a more diverse launch opportunity then does Ariane and based upon present information, does so at lower initial and reflight charged costs for the vertically mounted, 86" diameter Delta class payload, such as MUSAT Configuration A.

Based on a launch in October, 1982, the projected launch costs for MUSAT can be broken down as follows:

	$ M (for October, 1982 Launch	
	MUSAT Configuration A	MUSAT Configuration B
STS Launch		
Basic STS Charge	6.322	16.379
Reflight Guarantee	.083	.216
Optional STS Charges (including KSC facilities)	.895	.895
MDAC PAM-D Charges	4.096	4.152
TOTAL	11.396	21.642
Ariane Launch		
Basic Ariane Charge	19.785	19.785
Relaunch Guarantee	1.979	1.979
Communications Link	.050	.050
TOTAL	21.814	21.814

Further cost reductions are likely with STS payload launches for larger payloads as we move from the transition to the Shuttle optimized design era.

However, the impact of the STS launcher complexities on the User's planning, analysis and implementation manpower requirements dependent upon User philosophy, would tend to reduce the cost differential between the two systems. Also, it is anticipated that ESA will, at least initially continue to modify costs in an attempt to become competitive with STS and, as confidence in the reliability of this European launcher grows, external insurance costs will likely diminish. Further, by 1983, cost structures are likely to be greatly different for both launchers since policies have only been set for three years on STS and for the first five operational vehicles in the case of Ariane.

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