DETERMINATION OF THE AVAILABILITY OF APPROPRIATE AGED FLIGHT ROCKET MOTORS

Extension of Contract 953298

Prepared for:

JET PROPULSION LABORATORY
PASADENA, CALIFORNIA

STANFORD RESEARCH INSTITUTE
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January 11, 1974

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Submitted by: PATRICK J. MARTIN
Principal Investigator

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CONTENTS

ILLUSTRATION

I SUMMARY

Government and commercial participants in a national survey to identify surplus, aged solid-rocket flight motors have submitted data on 33 different motors that are available for a coordinated program of functional integrity testing. These motors are classified in the following three categories:

- Upper stage and apogee motors
- Sounding rocket and launch vehicle motors
- Jato, sled, and tactical motors.

Eight different upper stage and apogee motor designs are identified in the 24 motors available in that category; 9 different sounding rocket and launch vehicle motor designs are available in about a hundred motors included in a second category; and 16 different jato, sled, and tactical motors are available in the unquantified stocks of the third group. The principal owners of the motors are the Air Force and NASA, and Jet Propulsion Laboratory (JPL), Philco-Ford, Comsat, and Hercules own a few specific upper stage and apogee motors.

Nearly all of the motors are available now because their age exceeds the warranted shelf life. Ages range from 3 to 20 years with most falling into the 5 to 10 year group. Two apogee and one upper stage motor are considered flightworthy; perhaps a dozen motors in all are known to be defective; the remaining are considered in unknown condition at this time. Static test fixtures and shipping containers are generally available. Some manufacturing, inspection, and test records are available with the motors; the sources are known for those records not currently accessible.

The expressed preference for tests included testing at nominal flight conditions, at the design limits, and to establish margin limits. The principal failure modes of interest are case bond separation and grain bore cracking.

Performance and other principal data on the available motors cover a wide range as follows:

	Range
Gross weight (lb)	71 ⟶ 22,648
Length (in.)	24 ⟶ 357
Diameter (in.)	7 ⟶ 40
Burn-time (sec)	0.6 ⟶ 38.4
Maximum thrust (lbf)	1,100 ⟶ 115,000
Maximum pressure (lb)	225 ⟶ 2,255
Flame temperature (°F)	2,390 ⟶ 6,562
Case wall thickness (in.)	0.030 ⟶ 0.185

Double-base, composite modified double-base, plastic, acrylate, polysulfide, polyurethane, PBAA, CTPB, and PBAN propellants are contained in the motors, as case-bonded or cartridge-loaded grains. Steel, carbon, graphite, and silver-infiltrated tungsten throat inserts are available in the nozzles. Case materials include several steels, titanium, aluminum, and filament-wound glass.

A general test sequence was outlined to obtain the most useful data from each selected motor. Three potential beneficiaries of a coordinated test program are the Space Shuttle solid-rocket motor program offices, spacecraft prime contractors, and the solid-rocket motor companies. Selection of motors from the tabulated inventory will await indications of the interest and requirements of these beneficiaries.

The motors present an opportunity to obtain useful research data and to provide the above-named beneficiaries with characterization and design margin information on materials, components and motor designs leading to their specific requirements. Some of the available motors can be used to obtain generally applicable data on case-bonding, aged propellants, aged insulation, motor case growth and thermal degradation, and nozzle integrity.

II INTRODUCTION

The design, development, qualification, test, and production programs for solid-rocket motors on occasion result in the loading of flight motors that are not subsequently tested because of changes in program scope or direction, detection of manufacturing discrepancies, or imperfections of questionable effect on motor performance and repairability, transportation damage, or change in motor design requirements. Motors are also made surplus by cancellations, changes in satellite and spacecraft programs, design requirements, and by exceeding warranted shelf life in storage. The consensus of participants in a previous reliability study was that such surplus motors could yield useful data in a test firing program. It also was apparent that the necessary data were not assembled to determine the scope, costs, and schedules that would return the best yields from such a program.

The kinds of data and documentation needed include:

- Physical location and condition of the motors.
- Handling and test fixtures, and shipping containers.
- Manufacturing and inspection records.
- Test and flight data on the directly related motors and propellants.
- Failure modes and effects analyses.
- Design factors of the motors and major subsystems.
- Possible test sites.

Cost estimates are required for obtaining and testing of the motors. The schedule of availability is needed for those motors that are scheduled for future release to such a testing program. SRI was given a task by JPL on NASA subcontract 953298 to assemble these data.

A data solicitation letter and questionnaire forms were mailed to 32 selected individuals in government and contractor organizations with a known interest in the functional integrity of solid-rocket motors. The distribution list, letter, and form are reproduced in the Appendices to this report. Follow-up phone calls were made to most of the recipients.

The returned data were assembled in tabular form and supplemented with data from the CPIA Rocket Motor Manual and the motor manufacturers' brochures.

Motor problem priorities were developed from the flight failures reviewed in the initial apogee motor reliability study and from the expressed interests of the survey participants. These problems coincide with the failure modes of most concern. In current order of interest, the problems are:

- Aft end case/insulation/liner/grain bonds
- Grain bore cracks
- Low-temperature soak effects
- Motor integrity near burn-out
- Motor growth or distension at pressurization
- Ignition shock effects.

The problem priority assignment and the motor availability and condition data were coupled to develop a general test sequence that would yield cost estimates suitable for guidance in motor selection for the coordinated test program. The proposed test sequence includes:

- Grain surface hardness and visual inspection.
- Physical properties from excised specimens.
- Push and pull bond tests at aft case/insulation/liner/propellant interfaces.
- Pressure and temperature cycling and case expansion and contraction during cycles; X-ray after cycles.
- Static test/dissect for inspection and tensile tests.

Where motor integrity is judged adequate for static test, the tests recommended are:

- Low-temperature soak (whole motor/nozzle exit plane).
- Extended duration by grain-surface inhibiting or by nozzle throat area increase.
- Case and nozzle hot spots by grain-drilling or grain-slotting.

III DISCUSSION

Industry Survey

The solicitation correspondence was directed to rocket motor companies, spacecraft prime contractors, and government facilities with a known interest in solid-rocket motor design, development, test, evaluation, and procurement for use. Individuals with a previously expressed interest in margin testing of solid rockets or a current position of responsibility for motors at their facility were addressed in the correspondence. Subsequent telephone conversations with most of the solicited individuals further emphasized the importance of the effort and of their cooperation.

Seven of the respondents supplied data and identified motors that were available for the testing program. Eight others expressed interest in participating in the testing program and supplied comment on failure modes and on directions the tests could take to obtain data applicable to their requirements. Three organizations stated inability to participate in the survey because of lack of manpower or funds to conduct the inventory or to assemble the requested data or both. The numerous telephone conversations with the fourteen who did not prepare formal replies to the solicitation revealed that sufficient changes in mission had caused many government offices to lose interest in a program of this type; individuals in commercial organizations indicated an inability to maintain their informal and personal interest in the testing program because of other duties.

The results of the survey, supplemented with data from the CPIA Rocket Motor Manual and motor manufacturers' brochures, are tabulated in Tables 1 through 16.

Table 1

MOTORS AVAILABLE FOR TESTING: UPPER STAGE AND APOGEE MOTORS

Designator	Owner	Location	Approximate Age (years)	Unit Number	Quantity	Remarks
X248 Altair	NASA	Wallops	5 to 11	--	8	
TE-M-186 40 inch spherical	NASA	Wallops	9	--	2	
SR-12-1 Syncom	NASA-JPL	ETS	8	418	1	One motor in long-term storage (1974)
TE-M-521 Skynet I	Philco-Ford	Elkton	--	--	1	Aerospace Corp. submission
TE-M-184 25 inch spherical	NASA	Wallops	9	366	2	
SVM-1 Intelsat	Comsat	AFETR	5	--	2	
TX-306 Arpat	NASA	Wallops	9	--	4	
BE-3-A4 Athena,	Hercules	Bacchus	8	416	2	Core fins slipped; need igniters;
-A5 Sparta	Hercules	Bacchus	7	--	2	1 minor case bond; both need igniters and nozzles

Table 2

MOTORS AVAILABLE FOR TESTING: SOUNDING ROCKET AND LAUNCH VEHICLE MOTORS

Designator	Owner	Location	Approximate Age (years)	Unit Number	Quantity	Remarks
XM-68 Algol	NASA	Wallops	9 to 13	277	3	To be destroyed
XM-33 Castor plus Pollux	NASA	Wallops	5 to 12	237	24	
TX-77 Lance	NASA	Wallops	6 to 9	241	11	Includes 1-XM-45 canted nozzle version
RS-U-501 S II Ullage	NASA	KSC,* McGregor	3 to 7	441	14	McGregor recommended as test site
TE-82 Cajun	AF	--	--	354	--	
Javelin II	AF	--	--	448	--	
TE-M-29 Recruit	NASA/AF	Elkton/ Wallops	7 to 13	240	34	Elkton recommended as test site for 2
TE-M-424 SIC Retro	NASA	KSC, Elkton	4 to 5	--	5	Elkton recommended as test site
Gila IV	AF	--	--	490	--	

*Kennedy Space Center.

Table 3

MOTORS AVAILABLE FOR TESTING: JATO, SLED, AND TACTICAL MOTORS

Designator	Owner	Location	Approximate Age (years)	Unit Number	Quantity	Remarks
XM 41 Aerojet, Jr.	NASA	Wallops	6	290	1	
M8 Jato	AF	--	--	396	---	
X251 Talos Boost	AF	--	--	256	--	
X256 Terrier Boost	AF	--	--	257	--	
X240 Terrier Boost	AF	--	--	347	--	
X216 Terrier Boost	AF	--	--	258	--	
M88 Hercules Boost	AF	--	--	393	--	
X102 Sled Boost	AF	--	--	223	--	
Gosling	NASA	Wallops	13	244	6	
M60 Falcon (GAR-11)	AF	--	--	231	--	
Genie	AF	--	--	384	--	
M26 Littlejohn	AF	--	--	395	--	
M58 Falcon (GAR-1)	AF	--	--	219	--	
Zuni	AF	--	--	283	--	
5" HVAR	AF	--	--	288	--	
TE-M-483 ZAP	AF	--	--	488	--	

Table 4

MOTOR INVENTORY TABULATION KEY

(A) Condition
- 1 Flightworthy
- 2 Repairable for static test
- 3 Rejected for ________________
- 4 Shelf life exceeded
- 5 Unknown
- 6 Other*

(B) Accessories available
- 1 Static test fixtures
- 2 Vibration test fixtures
- 3 Shipping container
- 4 Spare igniters
- 5 Spare nozzles
- 6 Other*

(C) Inspection/test records
- 1 Available with motor
- 2 In archives or storage
- 3 Seek from manufacturer
- 4 Other*

(D) Kinds of records
- 1 Motor log book
- 2 Radiographic films
- 3 Propellant properties
- 4 Batch motor ballistics
- 5 Other*

(E) Preferred test program
- 1 Test at flight conditions
- 2 Test at design limits
- 3 Test to establish margin limits

(F) Failure mode(s) of interest
- 1 Case bond separation
- 2 Grain bore crack

(G) Suitable tests
- 1 Inerts examination
- 2 Ground storage/handling
- 3 Propellant mechanical properties
- 4 Low temp. firing at ____ °F
- 5 High temp. firing at ____ °F
- 6 High pressure firing at _____ Psia max.
- 7 Extended duration firing at ____ Psia max. and/or ______ seconds
- 8 High acceleration to test bond
- 9 Shuttle booster test data possibility
- 10 Temperature and pressure cycling at or over margin limits; radiographic inspection
- 11 X-ray; static test at nominal temperature
- 12 Other*

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*See Holloman Air Force Base (HAFB) letter that immediately follows this table.

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS 6585TH TEST GROUP (AFSC)
HOLLOMAN AIR FORCE BASE, NEW MEXICO 88330

REPLY TO ATTN OF: TKS

NOV 1972

SUBJECT: Available Rocket Motors in Holloman Test Track Inventory

TO: Mr. Patrick J. Martin
Stanford Research Institute
Menlo Park, California 94025

1. In response to your letter and questionnaire dated 22 September 1972, the following information is provided concerning rocket motors available in the Holloman Test Track inventory.

a. Ownership - All motors are Air Force property at the present time.

b. Location - Motors are located at Holloman Air Force Base, New Mexico, and Ammunition Depots throughout the United States.

c. Value - Maximum $5000.00 ea.

d. Motor Manufacturer and Designation - See Attachment 1.

e. Program/Contract/Receipt Date/Serial Number - This information available on some rocket motors but not researched for this correspondence.

f. Condition - Most of the rocket motors are five to ten years old. There are extremes, such as Nike motors, 15 years old, and five-inch rocket motors, 20 years old. Most have exceeded established shelf life. Some are rejects from Air Force inventory due to damage to flight hardware.

g. Inspection/Test Records - These records are not available in majority of cases.

h. Preferred Test Program - Effects of vibration and high accelerations for rocket motors in the Test Track environment is of interest.

i. Accessories Available - The Test Track is suggested as a means to dynamically test rocket motors and recover the motor hardware or the unfired motor. Reference attached handbook for additional information on the Test Track Facility. There is a static test stand located at the Test Track. This is a horizontal test facility capable of thrust load of one million pounds.

j. Kinds of Records - Information on batch Motor Ballistics can be obtained on most motors in the inventory but it is not immediately available.

k. Suitable Test - Effects of ageing determined through static ambient firing and ballistic properties tests are of most interest.

l. Cost per Test - Dependent on hardware, instrumentation and propulsion costs.

m. Test Documentation Preparation Time - Normally, test documentation can be completed within 45 days after test parameters are outlined in technical meeting.

2. The listing of rocket motors provides the variety of motors in the inventory, but use of any of the motors depends upon the acquisition cost of the motor, the quantity required for testing, and the information obtained that may be related to future sled test vehicle and propulsion designs. All information provided is for determination of feasibility of a test program, but the Holloman Test Track is not to feel obligated in any way until standard test documentation is prepared.

3. We are extremely interested in this program as beneficial information should be developed for every one involved. Please feel free to call Mr. Marvin D. Weber and write for additional information if needed.

FOR THE COMMANDER

George H. Chronis

GEORGE H. CHRONIS, Colonel, USAF
Chief, Test Track Division

2 Atch
1. Rocket Motor List
2. HAFB Facilities and Capabilities

2

Table 5

QUESTIONNAIRE RESPONSE: UPPER STAGE AND APOGEE MOTORS

Designator	Condition (A)	Accessories (B)	Records Location (C)	Kinds of Records (D)	Preferred Tests (E)	Failure Modes (F)	Suitable Tests (G)	Test Cost/Motor (thousands of dollars)
X248	--	--	--	--	--	--	--	--
TE-M-186	--	--	--	--	--	--	--	--
SR-12-1	1	1,2,3,4,5	1	1,3,4	3,2,1	1,2	11	$ 7
TE-M-521	1	1,2,3,4	1,2,3	1,2,3	3	1,2	4	--
TE-M-181	--	--	--	--	--	--	--	--
SVM-1	4	1,3	1,2	1,2,3,4	1	--	4,5	15
TX-306	--	--	--	--	--	--	--	--
BE-3-A4	3,3	1,2,3	2	2,4	2,3,1	1	12	7.5
BE-3-A5	1,3	1,2,3	2	2,4	2,3,1	1	12	11.5

Table 6

QUESTIONNAIRE RESPONSE: SOUNDING ROCKET AND LAUNCH VEHICLE MOTORS

Designator	Condition (A)	Accessories (B)	Records Location (C)	Kinds of Records (D)	Preferred Tests (E)	Failure Modes (F)	Suitable Tests (G)	Test Cost/Motor (thousands of dollars)
XM-68	3	--	--	--	--	--	--	--
XM-33	--	--	--	--	--	--	--	--
TX-77	--	--	--	--	--	--	--	--
RS-U-501	4	--	1,2,3	--	--	--	10	$1.5
TE-82	6	6	4	5	--	--	8	--
Javelin II	6	6	4	5	--	--	8	--
TE-M-29	4,3 & 6	6	1,2,3,4	5	--	--	8,10	1.5
TE-M-424	4	--	1,2,3	1	--	--	10	1.5
Gila IV	6	6	4	5	--	--	8	--

Table 7

QUESTIONNAIRE RESPONSE: JATO, SLED, AND TACTICAL MOTORS

Designator	Condition (A)	Accessories (B)	Records Location (C)	Kinds of Records (D)	Preferred Tests (E)	Failure Modes (F)	Suitable Tests (G)	Test Cost/Motor (thousands of dollars)
XM-41	6	6	4	5	--	--	8	--
M8	6	6	4	5	--	--	8	--
X251	6	6	4	5	--	--	8	--
X256	6	6	4	5	--	--	8	--
X240	6	6	4	5	--	--	8	--
X216	6	6	4	5	--	--	8	--
M88	6	6	4	5	--	--	8	--
X102	6	6	4	5	--	--	8	--
Gosling	6	6	4	5	--	--	8	--
M60	6	6	4	5	--	--	8	--
Genie	6	6	4	5	--	--	8	--
M26	6	6	4	5	--	--	8	--
M58	6	6	4	5	--	--	8	--
Zuni	6	6	4	5	--	--	8	--
5" HVAR	6	6	4	5	--	--	8	--
TE-M-483	6	6	4	5	--	--	8	--

Table 8

PRINCIPAL DATA ON AVAILABLE MOTORS: UPPER STAGE AND APOGEE MOTORS

				Maximum	Maximum	Weights	
Designator	Length	Diameter	Burn Time	Pressure	Thrust	Inerts	Grain
X248	58.2	18.0	38.4	225	3,020	59	445
TE-M-186	60.2	40.1	27.0	725	21,000	165	1,995
SR-12-1	24.1	12.1	19.6	258	1,100	11	61
TE-M-521	38.6	17.4	19.1	850	4,470	26	247
TE-M-184	41.6	25.1	16.6	571	7,640	42	478
SVM-1	33.1	18.0	16.2	465	4,830	30	163
TX-306	47.3	29.0	11.0	1,200	17,000	157	688
BE-3-A4	32.6	19.1	9.2	550	6,400	23	191

Table 9

PRINCIPAL DATA ON AVAILABLE MOTORS: SOUNDING ROCKET AND LAUNCH VEHICLE MOTORS

Designator	Length	Diameter	Burn Time	Maximum Pressure	Maximum Thrust	Weights Inerts	Weights Grain
XM-68	357	40.1	35.9	450	115,000	3,662	18,986
XM-33	233	31.0	27.3	759	70,800	1,441	7,313
TX-77	187	15.7	5.4	1,413	57,900	444	1,200
RS-U-501	89	13.0	3.7	1,080	23,200	146	336
TE-82	108	7.1	3.0	1,235	10,340	59	119
Javelin	101	9.0	1.8	1,668	38,282	102	239
TE-M-29	105	11.5	1.5	2,100	39,400	95	267
TE-M-424	84	15.2	0.6	1,748	91,000	225	278

Table 10

PRINCIPAL DATA ON AVAILABLE MOTORS: JATO, SLED, AND TACTICAL MOTORS

Designator	Length	Diameter	Burn Time	Maximum Pressure	Maximum Thrust	Weights Inerts	Weights Grain
XM 41A-J, Jr.	27	6.8	17.0	1,140	250 (Avg)	21	21
M8 Jato	34	11.0	12.0	1,000	1,000	84	71
X251	138	31.1	5.3	1,130	128,700	1,475	2,803
X256	157	26.8	4.0	1,325	72,200	627	1,202
X240	157	26.8	4.0	1,405	66,800	614	1,226
X216	147	17.0	2.9	1,200	54,000	587	746
M88	136	17.6	3.0	1,200	50,000	443	750
X102	52	11.4	2.2	1,450	12,100	124	143
Gosling	131	11.0	3.1	1,420	33,500	128	405
M60	32	8.3	2.1	1,400	7,000	24	60
Genie	66	17.4	2.2	1,570	39,250	166	327
M26	94	12.5	1.5	1,100	33,000	274	243
M58	37	6.2	1.4	1,650	5,900	15	31
Zuni	76	5.1	1.0	1,979	6,500	29	34
5" HVAR	51	5.0	0.9	1,690	6,400	60	24
TE-M-483	78	6.0	0.9	2,255	26,850	22	85

Table 11

PROPELLANT, GRAIN, AND IGNITER DATA: UPPER STAGE AND APOGEE MOTORS

Designator	Configuration	Propellant	Binder	AP* (percent)	AL† (percent)	Flame Temperature (°F)	Igniter Type	Igniter Location
X248	Slotted tube	BUU	D.B.	--%	--%	4,625	BPN-pyro	Aft
TE-M-186	9-Point star	TP-H-3034	PBAA	--	--	5,587	Pyro	Fore
SR-12-1	8-Point star/ cylinder	JPL540	PU	64	16	5,260	Alclo	Fore
TE-M-521	8-Point star	TP-H-3062	CTPB	70	14	5,662	Dual pyro	Aft
TE-M-184	9-Point star	TP-H-3034	PBAA	--	--	5,597	Pyro	Fore
SVM-1	Conocyl	ANB-3066	CTPB	73	15	5,836	BPN	Fore
TX-306	3-Point star	TP-H-8145	PBAA	68	17	5,716	Pyro	Fore
BE-3-A4	Slotted tube	DDP-80	D.B.	20	20	6,562	BPN	Fore

*AP = ammonium perchlorate.

†AL = aluminum.

Table 12

PROPELLANT, GRAIN, AND IGNITER DATA: SOUNDING ROCKET AND LAUNCH VEHICLE MOTORS

Designator	Grain Configuration	Propellant	Binder	AP* (percent)	AL† (percent)	Flame Temperature (°F)	Igniter	
							Type	Location
XM-68	8-Point star	ANP 2639	PU	--%	--%	--	Alclo	Fore
XM-33	5-Point star	TP-H-8038	PBAA	70	14	5,280	Pyro	Fore
TX-77	5-Point star	TP-E-8114	PS	72	2	4,926	Pyro	Fore
RS-U-501	4-Point star	RDS-509	CTPB	82	4	5,256	Pyro	Fore
TE-82	6-Point star	TP-E-3001	PS	71	--	5,000	Pyro	Fore
Javelin	Cylindrical	LPC-594A	PBAN	70	16	5,768	CuO/Al	Aft
TE-M-29	5-Point star	TP-E-8035	PS	74	--	5,138	Rolled tube	Aft
TE-M-424	12-Point star	TP-E-8104	PS	72	2	4,400	Pyro	Fore

*AP = ammonium perchlorate.

†AL = aluminum.

Table 13

PROPELLANT, GRAIN, AND IGNITER DATA: JATO, SLED, AND TACTICAL MOTORS

Designator	Grain Configuration	Propellant	Binder	AP* (percent)	AL† (percent)	Flame Temperature (°F)	Igniter Type	Igniter Location
XM41	Internal/external cylinder	AMT-2091	Acrylate	(AN)%	--%	2,390	Alclo	Fore
M8	Slotted tube	OGK	D.B.	--	--	--	B.P.	Fore
X251	Wagon wheel	ARP/AHH	D.B.	--	--	--	B.P.	Fore
X256	Dual prop cylinder	CAP/AHH	D.B.	--	--	--	B.P.	Fore
X240	Dual prop cylinder	CAP/AHH	D.B.	--	--	--	BPN	Fore
X216	3 Concentric rings	OIO	D.B.	--	--	--	B.P.	Fore
M88	3 Concentric rings	OIO	D.B.	--	--	--	B.P.	Fore
X102	Internal/external cylinder	AK-14	Acrylate	(KP)	--	2,960	Alclo	Fore
Gosling	6-Point star	RD2304G	Plastic	--	--	--	Powder	Fore
M60	5-Point star	TP-L-8006	PS	78	2	5,129	Pellet	Fore
Genie	12-Point star	ANP512DS	PU	70AP/12KP	--	4,772	Alclo	Fore
M26	4-Point star	ARP	D.B.	--	--	--	BPN	Aft
M58	5-Point star	TP-L-8237	PS	74	--	4,544	Jelly roll	Aft
Zuni	8-Point star	X-8	D.B.	--	--	--	B.P.	Fore
5" HVAR	Cruciform	JPN	D.B.	--	--	--	B.P.	Fore
TE-M-483	Tapered cylinder	TP-H-3210	HC	74	10	5,222	Pyrotechnic	Fore

*AP = ammonium perchlorate; KP = potassium perchlorate; AN = ammonium nitrate.

†AL = aluminum.

Table 14

NOZZLE AND MOTOR CASE DATA: UPPER STAGE AND APOGEE MOTORS

	Nozzle					Motor Case	
	Surface/ Throat	Throat Area	Expansion	Material			Nominal Thickness
Designator	(Kn)	(in^2)	Ratio	Insert	Shell	Material	(in.)
X248	182	7.28	26	Graphite	Composite	FWG	0.055
TE-M-186	230	19.1	13	ATJ	Composite	4130	0.050
SR-12-1	80	2.41	35	ZTA	410	410	0.013(?)
TE-M-521	286	2.56	58	G-90	Composite	Titanium	0.033
TE-M-184	190	8.79	14	ATJ	Composite	4130	0.030
SVM-1	102	4.2	33	AG/W	Composite	FWG	0.040
TX-306	213	8.25	20	Carbon	4340	4340	0.050
BE-3-A4	--	6.29	19	Graphite	Composite	FWG	0.080

Note: 410, 4130, 4340 are steel alloys.

Table 15

NOZZLE AND MOTOR CASE DATA: SOUNDING ROCKET AND LAUNCH VEHICLE MOTORS

	Nozzle					Motor Case	
Designator	Surface/ Throat (Kn)	Throat Area (in^2)	Expansion Ratio	Insert	Shell	Material	Nominal Thickness (in.)
XM-68	167	17.5	4.6	Graphite	1018	4130	0.055
XM-33	207	73.7	5.9	Graphite	1020	4130	0.110
TX-77	241	26.3	6.0	Graphite	4130	4130	0.125
RS-U-501	131	13.9	8.0	Carbon	Titanium	4130	0.075
TE-82	290	5.08	6.3	Carbon	7075	2014	0.164
Javelin	106	12.8	4.0	ATJ	4130	4130	0.080
TE-M-29	174	14.5	7.1	Graphite	4130	4130	0.080
TE-M-424	184	35.1	3.7	Graphite	D6Ac	D6Ac	0.014

Note: 4130, 1018, 1020, D6Ac are steel alloys; 2014, 7075 are aluminum alloys.

Table 16

NOZZLE AND MOTOR CASE DATA: JATO, SLED, AND TACTICAL MOTORS

	Nozzle					Motor Case	
Designator	Surface/ Throat (Kn)	Throat Area (in^2)	Expansion Ratio	Insert	Shell	Material	Nominal Thickness (in.)
XM41A, Jr.	2,265	0.18	7.5	1020	1050	1030/1040	0.185
M8	712	0.67	7.8	4130	4130	4130	0.205
X251	268	76.5	6.4	4130	4130	4130	0.150
X256	279	35.0	7.1	Carbon	4130	4130	0.172
X240	--	35.0	7.6	Carbon	4130	4130	0.093
X216	418	29.7	6.8	4130	4130	4130	0.100
M88	425	29.7	7.2	4130	4130	4130	0.114
X102	190	--	--	4130	4130	4130	0.200
Gosling	184	--	--	DEF13	DEF13	4130	--
M60	194	3.56	4.8	AGX	4130	4135	0.059
Genie	254	15.9	6.7	Carbon	A-106	4130	0.104
M26	173	20.4	4.7	1031	1031	1031	0.095
M58	253	2.27	8.6	Carbon	1020	4130	0.051
Zuni	142	3.02	2.5	Steel	Steel	7075	0.138
5" HVAR	216	2.4	--	Steel	Steel	Steel	0.19
TE-M-483	84	7.79	3.5	ATJ	250	250	0.040

Note: 1020, 1030, 1040, 1050, 4130, DEF13, 4135, 1031, 250 are steel alloys; 7075 is an aluminum alloy.

Shelf-Life Extension

The responses confirmed the diminution of the national solid-rocket industry and the change of interest away from adding to the fund of technology in this area. Nevertheless, the itemized motors in toto present an original opportunity to contribute to the technology.

The motors in the first two groups--upper stage and apogee, and sounding rocket and launch vehicle--are early manufacture of the current state of the art.* Most have been submitted as surplus because they have aged beyond the warranted or demonstrated shelf life. Life estimates for these motors were based on some aging data available from military rocket programs and some limited testing of certain insulations and adhesives, but the immediate use plans for each motor and the apparent rapid strides in motor technology justified minimum emphasis and expenditure of effort in motor-aging studies. Now, however, is the opportune time to make more precise determination of the actual aging ability of these motors to bring their characterization to a level comparable to the cartridge-loaded, cast double-base boosters available in the third category of the motor tabulation--jato, sled, and tactical motors.

Cost reduction presents an even stronger motivation than technology characterization for tests of the available aged motors. Because NASA and DoD have both expressed an intent to redress the balance between cost and performance to favor the former, the rocket community must find ways to reduce cost. Accurate shelf-life extension for solid-rocket motors (which are nonrepairable items) allows their less frequent direct replacement in missile and launch vehicle systems and possibly justifies less frequent detailed inspection of their condition. When the use of the propulsion systems has to be delayed beyond original schedules, a margin of shelf life might avoid motor replacement expense.

As a result of the inventory, the available motors present an original opportunity to accurately estimate some of the interactions among materials selected for their construction. Cases, adhesives, insulation, liner, and propellant have been in intimate contact, as have nozzle shells, insulation, and inserts. Some of the material pairs have been subjected to laboratory-simulated aging tests--but with mixed results. The migration of plasticizers and moisture across more than single boundaries and

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*The research community might question this definition of state of the art because of their awareness and regular contact with higher performance designs and formulations and materials, but flight motors made today embody most of the features of the motors listed in the inventory tabulation and are therefore current.

the edge oxidation effects on bonds are questions of real impact on motor design that have not been answered by the laboratory tests. Moreover, the argument that moisture has been identified and brought under control in the motor manufacturing processes now in use does not negate the need for more precise knowledge of the overall effects of moisture in earlier manufacture of the same design. Motor sterilization studies and at least one current tactical motor program have shown that water considered bound in hydrates or inorganic fillers in the insulation can, under certain conditions, migrate to the liner and cause motor failure. The problem must therefore be considered as current and unsolved.

Finally, because the motors do represent current designs and material combinations that will see additional manufacture and use, an original opportunity exists to identify aging effects that might be detectable by nondestructive testing techniques not available when the motors were first manufactured. In-situ instrumentation at material interfaces comes to mind as the most recent advance of some potential.

Critical Failure Modes

The motor inventory task, as conceived, was to include an assembly of the critical failure modes for each of the available motors. These failure modes were to furnish some guidance in the test plan as it was evolved.

A review of the design and development efforts for the upper stage and apogee boost motors revealed that nearly all of the failures identified during the test programs were attributable to manufacturing or process errors that were subsequently provided for by improved inspection and process control. The few design weaknesses showed up in noncatastrophic anomalies such as case "hot spots" or loss or loosening of a component such as a nozzle insert or thrust ring after static test. Design modifications were made and margins were increased in each instance so that detected incipient failures are not applicable to the available motors.

From the responses, case-bond failures and grain bore-cracking are easily identified as the two persistent failure modes of concern to the motor manufacturers and users. This is understandable in the light of industry knowledge of and control over the physical properties of the elastomers and propellant formulations in use. Accordingly, the test plan attempts to determine motor conditions leading to these two failure modes.

Potential Beneficiaries

Tabulation of the available aged motors and identification of their prime potential in cost-reducing, shelf-life extension supplied inadequate direction to the test plan preparation. Therefore, additional potential use of the motor testing program had to be developed for the following groups of users. The Space Shuttle motor developers were the first choice in order to allow timing of test data availability to assure its usefulness in their decisions. The spacecraft prime contractors were chosen as the second group because of their likely continued interest in motors based on the technology represented in the tabulation and because their decisions are based on private investment in some instances. The rocket motor manufacturers were the third group because they will be expected to confidently increase their shelf-life estimates in bids for NASA and DoD business.

For the Space Shuttle motor developers, motors can be selected and tested to yield useful data for:

- Cost reduction
  - Shelf-life extension for current auxiliary motor designs and propellants if it is decided to use Apollo technology in the shuttle motors.
  - Additional characterization of candidate materials, designs, and components before selections are made, if the next generation technology beyond Apollo is to be used.
  - Characterization of new, lower-cost materials and processes for manufacture to take advantage of newer case and nozzle materials.
- Performance improvement--margin and reproducibility determination on materials, designs, and components now available from Delta, Scout, Titan IIIC, Minuteman, and Polaris launch vehicles.
- Failure effects analysis--extent of vector deviations, case deformations, and skin or nozzle shell temperature excursions that might result from abnormal motor operation.

The spacecraft prime contractors, especially those with geosynchronous or deep space missions, can also obtain substantial benefit from a test program with some of the available motors. For example, launch vehicle anomalies in the past have made a delay in solid motor ignition compulsory or desirable; however, decisions have been made without the assurance that the motors would perform satisfactorily with the new temperature gradient from an additional exposure to temperatures of space. The test plan could yield additional data to aid such assurance.

In addition, some motor failures in space have occurred midway or late in the motor burn; nevertheless, questions on integrity of motor components, especially bonds between materials, in the combined thermal and flight load environment remain unresolved. Motor distension during pressurization is suspected as the source of propellant grain failure in one instance and is calculated but not measured for most motors. Data on both of these problems can be derived in tests on the tabulated motors.

The rocket motor manufacturers have selected materials, formulations, components, designs, and manufacture and test processes based on extensive government-funded aging and characterization programs. They have combined these selections in their motor designs. Additional confirmatory aging data are needed on these whole motors before contractors can commit themselves when NASA and DoD request shelf-life warrants as a contractual requirement. DoD will not accept the shelf-life limits of a very expensive nonrepairable item such as the motor as the life limit of the missile system. The Space Shuttle and other NASA launch vehicles will require flexibility in "stretch-out" without the penalty of solid rocket motor replacement for shelf-life expiration. Data can be obtained from testing of the tabulated motors to allow the motor manufacturers to improve their predictions.

Areas of Investigation

Fruitful areas for data development in the test plan were outlined by combining the reported condition of the motors with known problems of the identified potential beneficiaries. In order of importance, the areas are:

(1) Bonding (case/insulation/liner/grain)

- Integrity
- Strength
- Retention after exposure to
  - Moisture
  - Cold
  - Partial propellant burn
  - Oxidative attack

(2) Propellants

- Aged physicals
- Migration
  - Moisture
  - Plasticizers

(3) Insulation

- Aged physicals
- Migration
  - Moisture
  - Plasticizers
- Low-temperature shock effects

(4) Case

- Distension at pressurization
- Thermal degradation
- Load ring or attach points bonding

(5) Nozzle

- Erosion at entrance and throat
- Buildup at the throat
- Component bonding

Bonding of the case, insulation, liner, and grain is a persistent problem in solid-rocket motors. The area at the nozzle attach periphery has received special attention because of both its severe environmental exposure during motor burn and its importance to motor performance. All of the effort to date has still left voids in the knowledge of this area, but the aged motors now available can be conditioned and tested in environments that will help fill some of these voids.

Nondestructive testing (NDT) currently determines bond separation but not bond strength. Strength can be determined on selected motors either by conditioning to as low a temperature as necessary to cause separation or by push or pull tests on selected propellant surfaces in the vicinity of the aft port. These strength tests can be performed after exposure to moisture, oxygen, or ozone at the edge of the bond. The bond strengths can be determined after extended duration static tests that increase the severity of the thermal exposure or after quench of partially burned motors. The physical properties can be determined on a series of thin propellant/liner/insulation/case specimens to determine what gradients exist. Collectively, the data can allow conclusions on the strength margins available in this critical area of past failures.

In the instance of moisture, the bound water in the insulation--held as an inorganic hydrate or adhering to the hygroscopic grades of silica and carbon black--can be drawn across the liner interface by the very dry propellant and some heating above ambient. The effect of this moisture is detectable in the hardness and tensile properties gradient of the contacted propellant. The plasticizer migration from propellant across the liner to the insulation seems to be aided by this moisture differential. In both instances, the liner is being allowed to equilibrate with water and plasticizer but with an undetermined effect on its ability to bond insulation to propellant. Physical test specimens about 0.1 inch thick through the areas and across the interfaces of interest can yield significant new data toward establishing processing and storage margins. Such testing could increase confidence in motors of the selected designs manufactured under the tighter moisture and temperature controls that were imposed as a fix after earlier failures.

The insulation formulations used in the available aged upper stage, apogee, sounding rocket, and launch vehicle motors are not generally capable of performance at the lower temperature extremes (-65° F or so) of tactical motors, and performance at this extreme is not planned. The actual low-temperature capability has not been extensively characterized on fresh stock, and margins for aged insulation that has been exposed to liners and anhydrous propellant are unknown. The need for the margin determination arises when decisions are made to fire motors after extra exposure to low temperatures. Some of the margins can be estimated from tests on motors selected from the tabulation where these aged motors can be considered as worst cases for insulation performance at low temperatures.

Motor cases are subjected to hydrotest before loading, and the volume of liquid pressurant used to bring the case to the requisite pressure is customarily recorded. This is used as a gross measure of case volume growth. In a few designs where a fit is of concern (i.e., where a safe-arm appendage is near a dome area), specific areas are monitored for linear dimension changes during hydrotest. In other instances, caliper measurements are made before and after hydrotest to determine that elastic limits have not been exceeded. Growth differentials (distension) are not measured routinely in hydrotests of new motor case designs or during acceptance tests.

Explanations for one flight failure include case distension that stressed the propellant grain to failure in a dome region. Insufficient clearance between the motor wall and payload is possible where the distension is not fully understood. A series of caliper measurements on the available motors during pressure and temperature cycles could yield a useful catalog of distension data for motor and payload designers.

A scorched appearance following static tests of motors using filament-wound cases has generally resulted in a fix of additional insulation in the area, even though the strength margins or integrity of the case as a result of such thermal degradation were not determined. The load transfer ring or attach points are bonded to such motors by a combination of wound filaments and adhesives. Severe thermal degradation might allow loss or loosening of these fixtures and a shift of the motor axes. Aged motors can be selected for extended duration static tests and subsequent determination of strengths of the case and its attached fixtures to determine the thermal degradation margins of such components.

Finally, nozzles are a fit area of investigation during a test program for aged flight motors. Vector anomalies have occurred as a result of nozzle component fracture and erosion/loss. The aged motors can be expected to have undergone changes in the properties of the nozzle component resins and elastomers. After limited inspection and physical tests are made to determine that aging alone has not caused failure of bonds, extended duration low-temperature static firings with a temperature gradient across the nozzle can yield data toward better understanding of the margins.

General Test Sequence, Sampling, and Techniques

None of the motors were reported as recently inspected, so the general test sequence was developed to supply at least the minimal data needed to make the decisions either on static testing or dissection of the selected motors. The test sequence and selected testing techniques were limited to maintain the integrity of the motor so that each could be static-fired. Some of the survey participants expressed interest in tests to determine whether the motors were changing in ballistic performance from the nominal, but the test sequence was not developed to allow or attempt duplication of the original ballistics. The motor failures of current interest have occurred after low-temperature exposures and well into the motor burn-time, so the proposed tests emphasize the low-temperature environment and modification of the motors to extend the burning time. The test sequence is proposed to include:

- Review motor log, unpack, visually inspect, and obtain surface hardness measurements.
- Excise specimens for physical property gradient testing.
- Perform push/pull tests on case/insulation/liner/propellant bonds at aft closure and on critical nozzle bonds.
- Do pressure- and temperature-cycling with case distention measurements during cycles.
- X-ray or visually inspect for integrity.

Then, on motors judged suitable for static test:

- Repair excised areas and reduce burning surface by potting.
- Open nozzle throat by machining insert.
- Drill or slot propellant and nozzle insulation to introduce controlled hot spots.
- Install thermocouples.
- Condition, static test, and record chamber pressure and thermocouple data.

On motors selected for dissection:

- Saw or chemically mill ports, rings, and aft cross sections.
- Prepare and test specimens for physical property gradients determination.
- Expose and condition specimens for edge effects of moisture, oxygen, and ozone.

The review of the motor log book or other immediately available records, the unpacking, and the visual inspection of the motor, nozzle, and igniter are to be followed by surface hardness testing of the propellant and insulation surfaces accessible to the hardness tester. A comparison with the original values recorded at the time of motor loading is desirable, but it will be just as important to determine what gradients exist at about 0.1-inch or closer intervals going away from the insulation into the propellant and from edges into the bulk material.

Blanks can be excised for physical properties testing by cutting off about 1-inch by 3-inch pieces of star points (for propellant only) or by coring to the case (for interface specimens). A minimum core diameter of 3 inches is desirable to allow preparation of specimens in 0.1-inch increments oriented parallel to the wall.

The industry experience with strength tests on the aft bonds is limited probably because the margin is judged small enough by virtue of the bond separations found frequently enough on inspection. Few are willing to abuse or fatigue the bonds by push or pull tests. Bond-testing experience in the practice of bonding pull blocks to the interior insulation of filament-wound cases is applicable to assess bond strengths before lining and loading. This same technique or tapered plugs can be used to apply measured force to the aft bonded area. Surfaces in this area can be machined to reach the interfaces of most interest in the selected motors. Nozzle entrance sections, throat back-up sections, and exit cone insulation can be tested similarly.

Obtaining case dimension change data during pressurization and temperature cycling is a departure from the routine data obtained during such stressing. It should be done in this testing sequence to confirm the analyses that have been made on the cases as designed and to determine the net effect of fixes made in some of the development programs (i.e., extra local filament wraps to bond attach hardware or extra insulation thickness to eliminate scorching).

The static tests are expected to be conducted with minimal/expendable instrumentation and equipment in the test bay. Visual inspection and perhaps a minimum X-ray would be justifiable on the basis of the lower operating pressures of the extended duration firings and the general goal of a low-cost testing program.

Where the selected motors are to be static-tested, extended duration firings are generally obtainable by reducing the burning surface, or by opening the nozzle throat, or by a combination of these techniques. The propellant formulations are understood sufficiently to allow mixing of potting compounds that will bond adequately, and the motors have readily machined graphite or carbon throat inserts in all but a few instances. The desired hot spots will likely be in the aft area where the propellant is accessible for drilling or slotting to the desired depths.

Installation of thermocouples on the case and nozzle exterior, conditioning, and static-firing for pressure time and temperature time are routine.

Some motors will be found unsuitable for static test, but they are of a vintage and design to yield good aging-effect data on materials interfaces of interest. Such motors should be cut apart to obtain test specimens, and the cooperation of the Air Force should be sought for this because of its unique experience and equipment at Ogden, Utah. No other national or contractor facility appears to be as well-equipped for this kind of motor dissection. The prepared specimens then can be exposed, conditioned, and tested in a number of laboratories.

Test Plan Cost Estimates

An essential element of any test plan is cost. As originally conceived, the SRI task was to include estimates of cost for acquisition, refurbishment, shipping, and testing.

The survey disclosed that NASA and the Air Force own nearly all of the motors, and the original shipping containers also are available. No additional acquisition costs would be charged for these motors, and shipping could be on a government bill of lading (GBL). Because the submitted detail on the motors does not allow estimation of refurbishment cost in advance of an actual inspection and the test sequence provides for motor modification instead of restoration to original condition, the refurbishment costs were not estimated.

The test plan cost estimates are reasonably independent of motor size and condition up to the pressure and temperature cycle step because motor manipulation is unnecessary until the motor is to be transferred to the pressure test bay or the conditioning oven. All estimates assume a minimum 2-man crew for work on the motors up to about 300 pounds and 4-man crews for motors above that weight. Individual technicians are allowed to work on the laboratory specimens and testing. For test planning, the following man-hour requirements are estimated.

Operations	Man-Hours/ Motor
Review log, unpack, visually inspect	4
Surface hardness (10 sites)	1
Excise 3-inch core	4
Excise two 1-inch by 3-inch star points	2
Prepare and test 0.1-inch thick physical property gradient specimens	8
Push and pull aft bond tensile tests	4

The costs for work to be performed on the motor leading to static test are presented as a function of motor weight, for test planning purposes only, in Figure 1. Costs for dissecting motors have not yet been reviewed or discussed with the Air Force. Unfortunately, these costs only begin to cover the physical work and data assembly. The engineering time and costs to select the specific motors; pinpoint the sampling areas within the motors; and select the pressures, temperatures, and times for extended duration firing of the cycled and conditioned motor will likely be at least an order of magnitude greater than the physical handling costs.

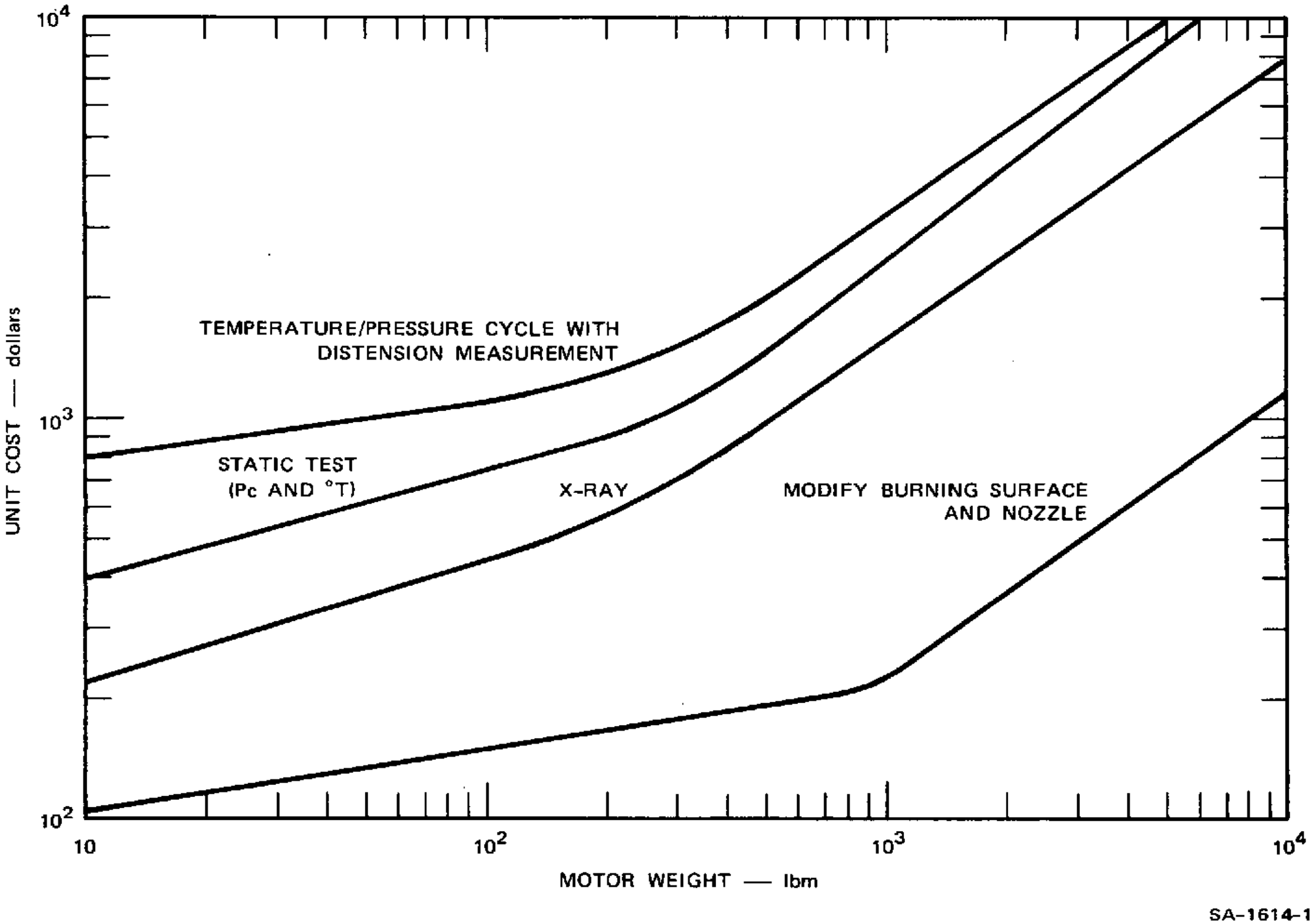

FIGURE 1 ESTIMATED COSTS, AS A FUNCTION OF MOTOR WEIGHT, FOR TEST PLANNING

IV CONCLUSIONS

(1) A national survey has identified and obtained preliminary data on surplus, aged solid-rocket flight motors.

(2) Laboratory and static tests can be performed on a number of these motors to obtain data that will extend shelf-life predictions and improve reliability of the aft case/insulation/liner/propellant bonds.

(3) The motors identified in the survey are a unique reservoir of aged motors representing many designs, components, materials, and formulations that are current state of the art.

(4) Detailed test plans must await evidence of interest from possible beneficiaries of the data to be generated.

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Appendix A

MAILING LIST FOR MOTOR SURVEY

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Appendix A

MAILING LIST FOR MOTOR SURVEY

Organization and Address	Individual
RCA Astro-Electronics Div. P.O. Box 800 Princeton, N.J. 08540	D. L. Balzer
SAMSO P.O. Box 92960 World Way Postal Center Los Angeles, CA 90009	LV/Col. E. A. Coy
United Technology Center P.O. Box 358 Sunnyvale, CA 94088	Charles Keyes
Aerojet Solid Propulsion Co. P.O. Box 13400 Sacramento, CA 95813	A. A. Helmar
Thiokol Chemical Corp. P.O. Box 241 Elkton, MD 21921	James Bowe
Lockheed Propulsion Co. P.O. 111 Redlands, CA 92373	Phillip G. Butts
NASA-Langley Research Center Hampton, VA 23365	Dean Crowder
NASA-Goddard Space Flight Center Greenbelt, MD 20771	Daniel Dembrow
Hughes Aircraft Company Space & Communications Group 1950 East Imperial Highway El Segundo, CA 90245	Edward Ellion

Organization and Address	Individual
TRW Systems Group Space Vehicle Division One Space Park Redondo Beach, CA 90278	Charles Meredith
NASA-Manned Spacecraft Center Houston, TX 77058	J. G. Thibodaux, Jr.
Aerospace Corporation 2400 East El Segundo Blvd. El Segundo, CA	Ellis Landsbaum
Philco-Ford Aeronutronic Div. Ford Road Newport Beach, CA	R. Hoffman
COMSAT Corp. c/o Hughes Aircraft Company Bldg. 366, MS 1126 P.O. Box 92919 Los Angeles, CA 90009	William Keck
OOAMA/MMEWM, Hill AFB, UT 84401	Anthony Inverso
TRW Systems, Mail Stop 01/2151 Redondo Beach, CA 90278	J. L. Myers
Hercules Inc. P.O. Box 98 Magna, UT 84044	Darrell L. Offe
Army Materiel Systems Analysis Agency (AMSAA) AMXSY-RE Aberdeen PVG GD, MD 21005	William T. Hirnyck
The Boeing Co. P.O. Box 3999 Seattle, WA 98124, Mail Stop 42-46	James P. Stebbins
Naval Weapons Center, Code 5562 China Lake, CA 93555	Dillard Bullard

Organization and Address	Individual
Thiokol, Wasatch Div. Brigham City, UT 84302	L. H. Layton
AMSMI-RKP, Redstone Arsenal Alabama 35809	Thomas H. Duerr
AFRPL(MKPB), Edwards, CA	Robert A. Biggers
Chemical Propulsion Info Agency JHU/APL, 8621 Georgia Ave. Silver Spring, MD 20910	Sidney E. Solomon
Naval Ordnance Station Indian Head, MD 22202	James H. Wiegand
Aerojet Solid Propulsion Co. Bldg. 0525, P.O. Box 13400 Sacramento, CA 95813	Kenneth Bills, Jr.
Rocketdyne Solid Propulsion Operations P.O. Box 548 McGregor, TX	W. H. Miller
Jet Propulsion Laboratory 4800 Oak Grove Drive Pasadena, CA 91103	W. Gin
Sandia Corporation P.O. Box 5800 Albuquerque, New Mexico	Larry Seamons
NASA Lewis Research Center 21000 Brookpark Road Cleveland, Ohio 44135	H. Bankaitis
NASA Marshall Space Flight Center Huntsville, Alabama 35812	Hans Paul

Appendix B

SOLICITATION LETTER AND QUESTIONNAIRE

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STANFORD RESEARCH INSTITUTE
MENLO PARK, CALIFORNIA 94025
(415) 326-6200

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September 22, 1972

Gentlemen:

The design, development, qualification, and test programs for upper stage, apogee, and high performance military solid rocket motors on occasion result in the loading of flight motors that are not subsequently tested because of changes in program scope or direction, detection of manufacturing discrepancies or imperfections of questionable effect on motor performance, or change in motor design requirements. Motors are also made surplus by exceeding guaranteed shelf-life limits, by cancellations and changes in satellite and spacecraft programs and by changes in design requirements. The necessary data are not now available to determine the scope, costs, and schedules of a coordinated test program that would help to verify the reliability and/or the design margins of such motors. The data needed to assess the feasibility of such a testing program include:

- Availability and condition of high-performance motors, test and handling fixtures, and shipping containers.
- Ownership and contact information to allow negotiation for testing of the selected motors.
- Critical failure modes of the motors and subsystems.
- Recommended test sites and facilities for probable tests.
- Estimated costs to obtain, refurbish, transport, inspect, test motors and document results.

On a current NASA subcontract to Jet Propulsion Laboratory (NAS7-100, Subcontract 953298), SRI is assembling the requisite data and recommending a testing program plan to extract the best motor test information from solid rocket motors no longer needed or suitable for flights. By this letter you are invited to participate by the submission of data on such hardware in your inventory, by suggesting tests that will better define margins or critical failure modes most relevant to your needs or designs, and by participation in the testing program as funding permits.

Attached are copies of a questionnaire that will supply the minimum data needed for initial screening; this information will be used as inputs in generating a recommended testing program plan. The form can apply to individual units or to multiples, so long as the characteristics and likely tests are, in your opinion, comparable. Please make your reply as complete as possible, but partial data are acceptable.

Following receipt of your reply I can arrange to visit you and discuss the information, data, and program in further detail. Prior questions can be directed by mail or phone (415) 326-6200, extension 4249. Replies are requested by 23 October 1972 to allow the task to proceed on schedule.

Your cooperation is appreciated.

Very truly yours,

Patrick J. Martin
Principal Investigator

PJM:ab
Enclosure

SOLID ROCKET MOTORS AVAILABLE FOR A RELIABILITY DEMONSTRATION TEST PROGRAM

Owner ____________
Location ____________
Estimated Present Value $ ______

Motor Manufacturer/
Motor Designation ____________
Program/Contract # ____________
Date Received/Serial # ____________

Condition
___ Flightworthy
___ Repairable for static test
___ Rejected for ____________
___ Shelf life exceeded
___ Unknown
___ Other ____________

Accessories Available
___ Static test fixtures
___ Vibration test fixtures
___ Shipping container
___ Spare igniters
___ Spare nozzles
___ Other ____________

Inspection/Test Records
___ Available with motor
___ In archives or storage
___ Seek from manufacturer
___ Other ____________

Kinds of Records
___ Motor log book
___ Radiographic films
___ Propellant properties
___ Batch motor ballistics
___ Other ____________

Preferred Test Program*
___ Test at flight conditions
___ Test at design limits
___ Test to establish margin limits

Failure mode(s) of interest
____
____
____

Suitable Tests*
___ Inerts examination
___ Ground storage/handling
___ Propellant mechanical properties
___ Low temp. firing at ___ °F.
___ High temp. firing at ___ °F.
___ High pressure firing at ___ Psia max.
___ Extended duration firing at ___ Psia max. and/or ___ seconds
___ Other ____________
____

Possible Test Sites or Facilities*
___ Ours at ____________
___ DoD at ____________
___ NASA at ____________
___ Other ____________

Estimated cost ($ or man-hours) for most desired test ____________

Estimate total elapsed time from receipt of approval or contract to test/documentation completion ____________

Remarks: ____________
____
____
____

Contact for follow-up:

____________ ____________ ____________
(Name) (Organization) (Phone)

* Indicate order of desirability by numbers