BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Trip Report - Space Storable Propellant Propulsion Technology Review and AIAA 4th Propulsion Joint Specialist Conference, Cleveland, Ohio, June 11 - 14, 1968, Case 720

DATE: August 6, 1968

FROM: C. Bendersky

ABSTRACT

The proceedings of a NASA/OART - Lewis Research Center sponsored Space Storable Propellant Propulsion Technology Review and the sessions attended at the AIAA 4th Propulsion Joint Specialist Conference are reported herein. The meetings were held June 11 - 14 at Cleveland, Ohio. Appendix I lists the OART agenda. Appendix II lists the preprints obtained.

(NASA-CR-97030) TRIP REPORT - SPACE STORABLE PROPELLANT PROPULSION TECHNOLOGY REVIEW AND AIAA 4TH PROPULSION JOINT SPECIALIST CONFERENCE, CLEVELAND, OHIO, JUNE 11-14, 1968 (Bellcomm, Inc.) 14 p

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MEMORANDUM FOR FILE

The writer attended a space storable review sponsored by NASA/OART - Lewis Research Center and selected technical sessions of the American Institute of Aeronautics and Astronautics (AIAA) 4th Propulsion Joint Specialist Conference during the period of June 11 - 14, 1968 in Cleveland, Ohio. The OART and AIAA sessions were not connected but rather the OART review (at Lewis Research Center) was scheduled to follow the AIAA as a convenience to the interested parties.

1.0 SPACE STORABLE PROPELLANT TECHNOLOGY REVIEW

These sessions were held the night of June 13 and all day June 14. The meeting was sponsored by OART/RP and Lewis Research Center to present to selected industrial contractors the complete scope of OART supported activity in the field of space storable propellants. Both contractor supported and in-house activities were reviewed. A copy of the agenda and a list of attendees are enclosed as Appendix I. No handouts were provided. These can be obtained from OART upon request.

The field of space storable technology is perhaps the area of liquid propellant technology receiving the greatest support from OART. The majority of the papers presented were concerned with combustion/ignition and material compatibility investigations.

The results of the OART programs thus far have demonstrated that:

(1) high combustion performance at design mixture ratios can be obtained with both major space storable families; FLOX/hydrocarbons and OF_2/B_2H_6. These combustion data more than justify the "optimistic" levels of performance assumed in this department's advanced design studies

of the MSSR[1] and PM-2[2].

(2) advanced materials based on graphitic structures have extremely high promise in providing light-weight combustion devices for fluorinated propellant systems. Results, particularly by the Marquardt Corporation, indicate that for these propellants, the requirements may be satisfied by free standing graphitic structures. If proven true, the conventional ablative and/or regeneratively cooled chambers will become obsolete. The inferences can not be underestimated. Several graphitic composite structures have been run at both 1000 psia and 100 psia without a realistic reduction in chamber lifetime (hours compared to 500 seconds for a LM ascent engine).

2.0 AIAA 4th PROPULSION JOINT SPECIALIST CONFERENCE

This annual event purports to present a comprehensive spectrum of liquid propulsion activities over the past year. Sessions on electric, nuclear, airbreathing, hydrodynamics, and selected hybrid and propulsion systems for tactical weapons were held.

The meeting was disappointing in the respect that most of the rocket sessions are more adequately covered in the CPIA[3] sponsored technical sessions.

The following sessions were attended by this writer:

I Propulsion Performance of the Saturn/Apollo System

II Launch Operations Effectiveness - Panel

III Advanced Materials for High Temperature Propulsion Applications

IV Space Storable Liquid Rocket Propulsion

V Advanced Pressurization System Technology

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[1] Macchia, D., Skeer, M. H., and Wong, J. - "Conceptual Design of Structural and Propulsion Systems for a MSSR Rendezvous Vehicle", Case 103-2, Memo For File, August 5, 1966.

[2] Marks, A. E. - "Small Space Propulsion Stage Preliminary Design", Bellcomm Technical Memorandum to be published.

[3] CPIA - Chemical Propulsion Information Agency of the John Hopkins University's Applied Physics Laboratory.

VI Low Cost Boosters (Confidential) (H. S. London also attended this session).

In general, the sessions presented state-of-the-art. A list of preprints obtained is enclosed as Appendix II. The first session described adequately the present Apollo propulsion units and provided some additional background. The second session did not address the title of "launch operations effectiveness" but was concentrated on a nuts and bolts discussion of facility (KSC) hardware and systems. Attempts by the audience to provoke a relevant discussion were nicely sidestepped particularly by the KSC panel members. The session on advanced materials was the technical highlight of the whole meeting. An AVCO[4] paper described the fabrication and properties of a new type of fiber-reinforced material system. Termed "Avco 3-D" the technique provides reinforcements oriented in three mutually perpendicular directions and eliminates the low inter-laminar strength constraint or ordinary reinforced plastic composites. All in all, the data presented show a break-through has been achieved, i.e., 3-D quartz phenolic has inter-laminar tensile strengths of 60,000 psi compared to 2300 psi for laminated quartz phenolics. The AVCO process may be important to reentry technology as well as rocketry.

The session concluded with a panel in which seven leading manufacturers of advanced materials discussed their activities. A summary of the material discussed is presented as Table I. Copies of pertinent data amplifying Table I were requested from each speaker.

The space storable propulsion session presented several in depth versions of data discussed at the OART session. The rest of the papers reported tests and studies that were archaic and need not be further discussed. An exception was the paper on $Li/F_2/H_2$ tripropellant combustion[5]. Combustion tests indicate that high levels of performance can be achieved leading to space systems having I_{SP} levels in excess of 520 seconds. The reported technology is the first open literature presentation of such success and leads to hope of a large performance potential for future chemical systems.

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[4] "Three Dimensionally Reinforced Ablative Rocket Engine Components", K. M. Jacobs, et al, AVCO Corporation, AIAA Paper 68-598.

[5] "Combustion Characteristics of the Fluorine/Lithium/Hydrogen Tripropellant Combination", H. A. Arbit et al, Rocketdyne - a Division of NAR. AIAA Paper #68-618.

The session on advanced pressurization system technology discussed several programs to evaluate more advanced liquid tankage pressurization schemes in comparison to existing helium or engine vaporized propellant systems. Of particular interest was the successful demonstration of MTI[6] (main tank injection). The propellants used in the study were MHF-5/ClF_5 for use in tactical weapons. MTI has been proposed for Big Dumb Booster (BDB) Application using N_2O_4/UDMA. This program is another data point (although small scale) lending credence to the BDB concept.

The session on low cost boosters was classified. H. S. London also attended this session. A paper by Aerospace Corporation derived the analytical costing techniques used to justify the "low cost" pressure fed approach versus competing solid boosted competitors. A Lockheed paper[7] reported an analysis which showed no clear cut advantage in the pressure-fed low cost approach. Later discussion indicated that the cost scaling laws used by Lockheed may be invalid and unduly penalized the low cost liquid system.

A Martin company paper (inserted instead of a cancelled McDonnell Douglas paper) studied the low cost system for use as strap-ons to advanced Titan family configurations. The Martin results showed that engine throttling may be necessary and that a variable area injector may be required. This impact on low cost was conveniently not amplified.

The session was concluded by a panel discussion on "Engines In Low Cost Boosters." The members were:

J. C. Moise	Aerojet General
G. W. Elverum	TRW System Inc.
D. Ordahl	United Technology Center
S. Iaccabellis	Rocketdyne Division of NAR

The panel discussion, directed by K. Chandler of MSFC and D. Ross RPL, EAFB were lively. The philosophies presented were patently parochial. For example, D. Ordahl neatly proved that the Hybrid system was as good as bipropellant liquid systems. Rocketdyne said not to overlook cheap pump-fed systems based on existing reliable Rocketdyne propulsion. (Technique remove requirements,

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[6] "Main Tank Injection for Packaged Liquid Missiles", Foster and Howell, The Martin Marrietta Co. AIAA Paper 68-627.

[7] "Simplified Liquid Booster Stage Cost Comparisons", R. W. Goldin, Lockheed (LMSC). AIAA Paper 68-813 (Unclassified).

downrate performance, reduce testing, etc.). The session was a good forum for discussion. Ross said the Air Force at RPL was funding or about to fund deepening studies to justify hopes for the approach. All members of the industry are anxiously awaiting these results.

Charles Bendersky

1013-CB-pap C. Bendersky

Attachments

AIAA Fourth Propulsion Joint Specialists Conference

Advanced Materials for High Temperature Propulsion Applications

NEW MATERIALS TECHNOLOGY - PANEL PARTICIPANTS

PANEL MEMBER	COMPANY ADDRESS	MATERIALS	STATUS OF MATERIALS	AVAILABILITY	PUBLISHED DATA AVAILABLE	TYPE OF DATA AVAILABLE
Donald H. Leeds	Super Temp Company Division of Ducommun Inc. Development Engrg. Dept. 11120 S. Norwalk Blvd. Santa Fe Springs, Calif.	a. RPG (reinforced pyrolytic graphite) alloys b. carbon foam c. fine-grained graphite	Samples in stock, parts made to order. Materials a and b are in the commercially available stage; d is in the development stage.	Made to order billets, seamless cylinders and cones, nozzles, thrust chambers, leading edges.	Brochures available on RPG alloy material only.	Room temperature compressive strength, densities; high pressure arc tunnel data, and torch tests.
Douglas C. Wise	The Carborundum Company New Products Branch Research & Development Div. P. O. Box 337 Niagara Falls, New York	Carb-I-Tex series (graphite-carbon fiber reinforced graphite-carbon), and other refractory hard metal carbides and borides.	Limited stock, other shapes by quotation only.	Shapes from simple blocks to complex nozzles can be manufactured or machined from Carb-I-Tex.	Brochures available.	Mechanical and physical properties, room temperature and elevated temperature.
J. H. Brannan	Union Carbide Corporation Carbon Products Division 270 Park Avenue New York, New York	a. "Grafoil" lightweight high temperature insulation and seals b. Fiber-reinforced graphite c. "Thornel" high modulus, high-strength graphite fibers	Material a is in stock; b and c are in the developmental stage.	Made to order.	Brochures available.	Room temperature physical property data is available, some high temperature data is available.
R. K. Carlson	Poco Graphite, Inc. 1200 Jupiter Road Garland, Texas	POCO AXF-5Q, a synthetic graphite	Material in stock.	Monolithic rectangulars up to 8"x18"x2" or cylinders up to 8" in dia. x 14" length.	Brochures and published report data available.	Broad range of room and elevated temperature physical and mechanical properties.
Donald W. Petrasek	NASA Lewis Research Center Materials & Structures Div. 21000 Brookpark Road Cleveland, Ohio	Refractory metal fiber nickel alloy composites.	Experimental	Experimental	"Refractory Metal Fiber Nickel Alloy Composites for Use at High Temperatures", NASA TM X-52342, 1967	Tensile and stress-rupture data at 2000 and 2200°F
Osborne L. Rider	FMC Corporation Chemical Research and Development Center P. O. Box 8 Princeton, New Jersey	AVCERAM-CS ablative reinforcing fibers composed of carbon and silica interspersed on a molecular scale.	Production	Fabric in stock and made to order.	Article in J. Poly. Sci., Part C, No. 19, pp. 267-281 (1967). FMC Data for Industry Number 102	Phys. and mech. properties at room temperature, mech. properties at 500°F, firing data: NOMAD Program.
Stanley Greenfield	Rocketdyne A Division of NAR Corp. Research Division 6633 Canoga Avenue Canoga Park, Calif.	Nine alloys based on Columbium, Tantalum, Molybdenum and Tungsten	Research on use as chamber cooling tubes.	(Not Applicable)	Technical Report AFRPL-TR-68-28, Jan. 68, Refractory Tube Test Chamber and Materials Evaluation Program, Final Report	Data classified.

TABLE I

JUNE 12, 1968

APPENDIX I

SPACE STORABLE REVIEW AGENDA

CONTRACT	TITLE	SPEAKER/TECHNICAL MONITOR	ORGANIZATION
	Welcome	I. A. Johnson	LeRC
June 13, 1968	Introduction	A. O. Tischler	OART
GENERAL TOPICS			
	Survey of NASA/OART Space Storable Propulsion Programs	F. Stephenson, Jr.	OART
*NASw-1644	Space Storable Propulsion System Comparison	J. Piper/ J. Suddreth	LMSC
COMBUSTION AND KINETICS			
NAS7-438	Basic Ignition Study - S/S Propellants	B. Breen/R. Kushida	Dyn Sc.
NAS7-660	OF_2-B_2H_6 Vacuum Ignition	T. Seamans/ R. Rowley	RMD
In-house	Vacuum Ignition	J. Rollbuhler	LeRC

CONTRACT	TITLE	SPEAKER/TECH. MONITOR	ORGAN.
NASr-183	Investigation of S/S Kinetics	L. Dauerman/T. Male	NYU
NASw-1293	Nozzle Kinetic Analysis	W. Burwell/P. Herr	UAC
NASw-1229	Nozzle Performance Evaluation	B. Waldman/P. Herr	R/D
In-House	FLOX-LPG Screech and Performance	J. Wanheinen	LeRC
June 14, 1968			
NAS3-11199	Space Storable Propellant Performance	S. Clapp/L. Gordon	R/D
NAS3-11200	Space Storable Propellant Performance	J. Mageean/L. Gordon	TRW, Sys.
In-House	S/S Combustion Device Technology	R. Riebling	JPL
In-House	Advance Combustion Devices	R. Riebling	JPL

TIME	CONTRACT	TITLE	SPEAKER/TECH. MONITOR	ORGAN.
HEAT TRANSFER AND COOLING				
	NAS7-659	OF_2-B_2H_6 Boundary Reactions	H. Mueggenburg/ R. Rowley	AGC
	*NAS7-304	Chamber Design for S/S Propellants	E. Zettle/C. Foster	R/D
		BREAK		
	NAS7-555	Advanced PG for Thrust Chambers	C. Coulbert/W. Tyler	TMC
	NAS3-11215	Thrust Chambers for S/S's	C. Coulbert/P. Herr	TMC
	NAS3-11184	Thrust Chambers for S/S's	F. Arndt/P. Herr	TRW, Sys.
	In-House	Investigation of Ablative Chambers	J. Winter	LeRC
	In-House	Throat Inserts for Ablatives	J. Winter	LeRC
		LUNCH		
	NAS3-7955	Coatings for Regen Engines	W. Lewis/R. Dusha	AGC
	NAS3-10294	Investigation of LPG's with Flox	A. Masters/J. Gregory	R&W

TIME	CONTRACT	TITLE	SPEAKER/TECH. MONITOR	ORGAN.
	* NAS3-11190	S/S Regen Cooling Study	P. Mitchell/J. Gregory	P&W
	NAS3-11191	S/S Regen Cooling Study	R. Pauckert/J. Gregory	R/D
ENGINE SYSTEMS				
	NAS3-7950	Flox-Methane Pump-Fed Engine	J. Colbert/L. Gordon	P&W
		BREAK		
PROPELLANTS				
	In-House	Propellant Chemistry	R. Riebling	JPL
	In-House	Materials Compatibility	H. Stanford	JPL
	In-House	Liquid Propellant Expulsion	H. Stanford	JPL
	NAS7-473	Gelled Space Storable Propellants	R. Globus/D. Young	ACG
		CLOSING REMARKS	A. O. Tischler	OART
		ADJOURN		

* AIAA Papers

SPACE STORABLE PROPELLANT PROPULSION TECHNOLOGY REVIEW

June 13 - 14

L. Aceto	Pratt & Whitney
F. Arndt	TRW Systems
T. E. Bailey	Pratt & Whitney
D. Barnes	Aerojet
C. Baulknight	Grumman
C. Bendersky	Bellcomm
G. W. Burge	Mc Donnell Douglas
H. Burge	TRW Systems
H. Burlage	JPL
R. Burry	Rocketdyne
W. Burwell	United Aircraft
R. Cannova	JPL
J. Chew	Pratt & Whitney
S. Clapp	Rocketdyne
J. Clark	Picatinny
J. Colbert	Pratt & Whitney
C. Coulbert	Marquardt
L. Dauerman	N.Y. University
G. DiSalle	G. E
D. Edgecomb	Battelle
D. Fester	Martin
J. Friedman	Rocketdyne
W. Gaubatz	Mc Donnell Douglas
I. Glasser	Marquardt
R. H. Globus	Aerojet
A. Goldford	LTV
S. Greenfield	Rocketdyne
B. Hankins	Boeing
S. Iaccobellis	Rocketdyne
A. Jensen	CPIA/APL
Don Jones	N. A. Rockwell
W. Kaminski	P&W
J. Keilbach	United Aircraft
W. Lewis	Aerojet
W. Lien	Marquardt
S. Lukens	Martin
J. Mageean	TRW Systems
A. Masters	Pratt & Whitney
C. Mc Gough	Aerojet
P. Mitchell	Pratt & Whitney
W. Mittelbach	Mc Donnell Douglas
H. Mueggenburg	Aerojet
C. Nagai	Rocketdyne
H. Neumark	Allied
J. Oberstone	Bell Aerosystems
R. Pauckert	Rocketdyne
J. Piper	Lockheed
W. Powell	JPL
R. Riebling	JPL
S. Rosenburg	Aerojet
H. Stanford	JPL
R. Schmiedtke	Pratt & Whitney
T. Seamans	Thiokol
J. Streetman	GDC
E. Trachenko	Dynamic Sciences
W. Trent	Mc Donnell Douglas
Warren Wade	Rocketdyne
C. D. Weimer	United Tech
Irwin Wishner	Grumman
E. Zettle	Rocketdyne
A. Zimmerman	TRW
L. Zune	Dynamic Science

NASA

C. E. Nichols	Langley
D. E. Schmertzing	Goddard
B. Lamb	Headquarters
F. Stephenson	"
R. Levine	"
R. Rollins	"
J. Suddreth	"
A. Tischler	"
K. Chandler	Marshall
E. Gomersall	Ames
J. Winter	Lewis
J. Rollbuhler	"
R. Salmi	"
R. Duscha	"
P. Herr	"
J. Gregory	"
L. Gordon	"
T. Male	"
I.A. Johnsen	"
R. C. Kohl	"
R. Grey	"
H. Bloomer	"
H. Douglass	"
D. Nored	"
C. Aukerman	"
S. Cohen	"
E. Edelman	"
H. Valentine	"
E. W. Conrad	"

APPENDIX I - ATTENDANCE LIST

APPENDIX II

1. No. 68-566, Apollo Reaction Control Systems, Chester A. Vaughan, MSC.

2. No. 68-567, Engines for Manned Spacecraft, Charles W. Yodzis, NASA-MSC.

3. No. 68-569, Development of LOX/RP-1 Engines for Saturn/ Apollo Launch Vehicles, Leonard C. Bostwick, NASA-MSFC.

4. No. 68-574, Application of High Density-Impulse Nuclear-Rocket Propellants in Aerobraking Spacecraft Assemblies, W. L. Dowdy, Space Division of North American Rockwell Corp.

5. No. 68-587, Nuclear Propulsion System Requirements Based on Future Mission Applications, C. D. McKereghan and F. M. Friedlaender, Lockheed Missiles and Space Company.

6. No. 68-588, Manned Interplanetary Mission Modes for Nuclear Propulsion Systems, A. R. Chovit, G. M. Callies, G. W. Cannon, and L. D. Simmons, TRW Systems Inc.

7. No. 68-589, Nonintegral Burn of Nuclear Rockets - An Approach to Low Cost Space Exploration, S. Gronich, R. J. Holl, and K. P. Johnson, McDonnell Douglas Corp.

8. No. 68-590, Common Nuclear Module for Planetary Exploration, J. F. Dollard, Boeing Company.

9. No. 68-598, Three-Dimensionally Reinforced Ablative Rocket Engine Components, K. M. Jacobs, A. T. Laskaris, and J. W. Herrick, Avco Corporation.

10. No. 68-611, Nuclear Rocket Materials Program, J. J. Lombardo and C. W. Funk, Aerojet General Corp.

11. No. 68-618, Combustion Characteristics of the Fluorine/ Lithium/Hydrogen Tripropellant Combination, H. A. Arbit, R. A. Dickerson, S. D. Clapp, and C. K. Nagai.

12. No. 68-656, Analysis and Design of a Hybrid Terminal Stage, P. H. Bialla and M. B. Adams, Douglas Aircraft Company.

13. No. 68-812, An Advanced Cryogenic Core Concept for a Flexible and Economical Delivery System, Edward W. Gomersall and Robert E. Slye, NASA/OART.

14. No. 68-813, Cost Projection for Simplified Liquid Stage, R. W. Goldin and G. T. Moe, Lockheed Missiles and Space Company.

BELLCOMM, INC.

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From: C. Bendersky

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