SSEH 9 March 1967

Comments on R. C. Hall's, "The Agena Satellite"

SSEA

1. Just a few comments on SP's security review of Hall's "Agena" for whatever they are worth: There is a possibility, perhaps remote--depending on the state of my paranoia at the moment--that Dr. Emme is trying, with some assistance from Hall, to embarrass SSD. They probably know each other fairly well and its a fair supposition that Emme already has copy of Hall's original paper--if he is a normal kind of Machiavellian, red blooded historian like I think he is.

2. However, to be completely candid, I think that SP did an inexcusably bad job of review, obviously in haste, and deleted good, important historical material for no other reason, apparently, than to be sure nothing got through.

3. Comments on deletions:

Page 6 This deletion is sound editing without commenting on the propriety of Air Force editing not related to either security or sensitivity.

Page 9 This seems to be a good editing change.

Pages 10-11. Deletion of these paragraphs doesn't make sense. Any well informed scholar-scientist-historian-Russian would know all about these implications. The second paragraph is also based on sources open to any researcher. I agree that the last sentence of the second paragraph should be cut; "Implementation . . . ." Deletion of the third paragraph is the least defensible. This censorship implies that SP believes that if these comments were censored all knowledge of satellites and Agenas would disappear.

Page 16 This material would be shaky without revision. Changing a few words would also remove the presumed objectionable material. This kind of shotgun deletion is a little offensive. The difference between a simple satellite and a certain level of sophistication certainly is no secret. So item 4 could have been revised and the paragraph would be o.k.

Page 20 Why take out ". . .(Agena A) and (Agena B) . . . ." here and keep it some place else?

Page 21 This deletion is a little far out. Any researcher can find an unclassified contract number, or the date of an award of a letter contract.

Page 35-36 Omitting any references to Agena payload recovery doesn't change anything--like common knowledge that Agena carries recoverable payloads. Information in the two paragraphs can be found in AW, Missiles and Rockets, and less well known but unclassified scientific papers.

Page 38 This information is already available in unclassified sources. If identification of the malfunction was a problem why not just delete the offending sentence?

Page 39 40 Hardware standardization or system standardization follow certain well known steps or changes that are well known by any engineer; the questionable sentences could have been deleted.

Pages 40-41 What is so sensitive about production problems? Especially when Lockheed is willing to talk about its own. Everybody has them. Perhaps a sentence could have been revised here and there.

Page 44 Cutting out this paragraph--other than a sentence or two perhaps--doesn't seem reasonable. This is straightforward development history that is neither sensitive nor classified.

Page 45-46 Could less explicit language or technical detail been omitted without deleting entire pages? Admittedly there may be too much detail here.

Page 47 Completely acceptable paragraph. If SP wants to keep kidding people who know better references to military space programs and payload ejection could have been easily taken out.

Bob Piper

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

IN REPLY REFER TO: EH

February 10, 1967

Col. Francis X. Kane, USAF
Space System Division
Air Force Unit Post Office
Los Angeles, California

Dear Duke:

It was good to hear from you and to learn of your pleasures with This New Ocean. We are pleased with your new responsibilities and congratulate you with best wishes.

R. Cargill Hall of Lockheed Missile and Space Company prepared an excellent paper on the "Agena Satellite Booster" for presentation at the AIAA History Committee session on the "Innovation Process" in Boston, December 2, 1966. It was unable to get but a small portion of this paper cleared by SSD for this presentation. Washington cleared all that SSD cleared. Now new AIAA President Harold Luskin is very desirous that we publish all the Innovation papers in book form, and I am editing same. I requested Lockheed to initiate a re-cycle on Hall's original paper in the hope that more of the great USAF story on the Agena might appear in printed form than Hall was able to deliver in Boston. Any R&D with a new technology involves problems but the Agena history is one of terrific success which bears public print, and without necessarily going into sensitive operational areas. The recent Lockheed attempt was apparently stillborn, as the enclosed letter documents.

Would you check on this matter for us? Beyond the AIAA spinoff there is also a NASA historical requirement to have a basic Agena text to refer to in our Ranger, Mariner, Gemini and other histories. If liberation of more of Hall's paper is not possible, the NASA Historical Archives requires a copy of the classified text for reference use. In any case, we would appreciate any help or suggestions you might make on this matter.

Give our warm regards to your Historian, Piper, and our other good friends in SSD. You may find Robert Perry and Al Goldberg of RAND solid supporters of the historical approach, and Stan Miller of NASA's WBO perhaps of help to you on NASA matters.

Yours sincerely,

Gene

Dr. Eugene M. Emme
NASA Historian

Encl:
Lockheed letter

[redacted]

20 OCT 1966

Lockheed
MISSILES
& SPACE
COMPANY

LMSC/583322

October 19, 1966

Subject: Clearance of Technical Paper

To: Hq., SSD
Attention: Gene Alberts (SSEA)
Air Force Unit Post Office
Los Angeles, California 90045

Enclosure : (a) Six (6) copies of a technical paper entitled "The Agena Satellite"

1. Enclosure (a) was prepared by Mr. R. Cargill Hall of Lockheed Missiles & Space Company.

2. Enclosure (a) was prepared at the invitation of the History Committee of the AIAA and is a history of the origins and development of the Agena satellite. Selected portions of the paper will be read at the History Committee Session on December 1, 1966 at the Third Annual AIAA Meeting to be held in Boston, Massachusetts. This paper will also be printed and distributed through the AIAA.

3. Enclosure (a) is submitted for your review and clearance prior to release.

4. Lockheed Missiles & Space Company has tentatively determined that this material is unclassified, technically accurate, suitable for release and requests confirmation of this status. The material identified herein should be handled in accordance with the procedures established for CONFIDENTIAL information until final determination as to classification is made by the appropriate military authority.

Very truly yours,

Rockwell Hollands
Rockwell Hollands
Manager, Public Information

Mr O'Brien called 20 Oct 66 LMSC deadline to AIAA is 15 Nov 66

RH:blc

"If enclosures are withdrawn or not attached the classification of this correspondence will be cancelled in accordance with Paragraph 25e of Air Force Regulation 205-1." [redacted]

A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION

SUNNYVALE, CALIFORNIA

SSEA 0774

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS SPACE SYSTEMS DIVISION (AFSC)
AF UNIT POST OFFICE, LOS ANGELES, CALIFORNIA 90045

Lt Col Ward Millar (SSE)

Dear Ward:

Dr. Emme of NASA sent me the attached letter concerning the paper on Agena and asked me to discuss it with you. After you have read the two attachments, please give me a call.

FRANCIS X KANE, Colonel, USAF
Director of Advanced Planning

2 Atch
1. Ltr from Dr. Emme, NASA, 10 Feb 1967
2. Ltr from Lockheed Missiles and Space Co., dated 2 Feb 1967

Agena

Keep this copy of the History on file — Hard & get one this complete on Agena. EA 8 Dec 67

HOLD until Dec 68 & give TO SMEH EA 8 Dec 67

SSEA-0879

File with our letter to Lockheed this subject. 6 Feb.

Lockheed
MISSILES
& SPACE
COMPANY

February 2, 1967

Lt. Colonel Ward M. Millar, SSEA
Director of Information
Air Force Space Systems Division
Air Force Unit Post Office
Los Angeles, California

Dear Colonel Millar:

Replying to your letter of January 27 concerning the request of NASA historian Eugene Emme for the "complete copy" of Cargill Hall's paper on the Agena, delivered at the AIAA meeting in Boston on December 2. I have advised Mr. Emme of your decision.

I have also talked to Mr. Hall relative to the background of this request, and Mr. Hall tells me that Mr. Emme was chairman of the AIAA session at which Mr. Hall's cleared paper was presented, and that Mr. Emme was aware that sections of Mr. Hall's original writing had been deleted.

Mr. Hall states that he did not submit his original writing to Mr. Emme, and that he did not describe to Mr. Emme what had been deleted. Mr. Emme, according to Mr. Hall, stated that he would seek a copy of the "original" paper for the NASA archives, with the understanding that anything which might be sensitive would be properly safeguarded in the NASA archives.

Mr. Hall states further that Mr. Emme mentioned that because the Agena is an important component of many NASA programs, NASA would like to have its files as complete as possible.

I am enclosing for you a copy of my letter to Mr. Emme, suggesting that any further correspondence on this matter be with you.

Sincerely,

Rockwell Hollands

Rockwell Hollands
Manager, Public Information

RH:blc

cc: Cargill Hall

Lockheed
MISSILES
& SPACE
COMPANY

February 2, 1967

Mr. Eugene M. Emme
NASA Historian
Office of Policy Analysis
NASA Headquarters
400 Maryland Avenue, S.W.
Washington, D. C.

Dear Mr. Emme:

Last December you requested a "complete copy" of the paper on the Agena delivered by [illegible] of Lockheed Missiles & Space Company at the AIAA meeting in [illegible], December 2.

We referred your request to the clearance authority for the paper, headquarters of the Air Force Space Systems Division at El Segundo, California.

This headquarters now replies that "the paper that was cleared for public release was the complete text of Mr. H[illegible]'s presentation and can be made available to NASA." I understand from Mr. [illegible] that you have a copy of the cleared paper presented at the AIAA session, of which you were chairman.

I suggest that any further inquiry concerning this paper be addressed to Lt. Colonel Ward M. Millar, Director of Information, Air Force Space Systems Division, Air Force Unit Post Office, Los Angeles, California.

Very truly yours,

[illegible] Hollands
Manager, Public Information

RH:blc

cc: Lt. Col. Millar

SSEA 27 Jan 1967

Request for Agena Paper from Mr. Emme of NASA

Lockheed Missiles & Space Company
ATTN: Rockwell Hollands
Manager, Public Information
Sunnyvale, Calif 94088

1. Reference is made to the request from Mr. Emme, NASA Historian for the "complete copy" of Mr. Hall's paper on the Agena, presented at the AIAA meeting in Boston, 2 Dec 66.

2. The paper that was cleared for public release was the complete text of Mr. Hall's presentation and can be made available to NASA.

3. We would appreciate any information readily available that would indicate what comments -- and the source of these comments -- prompted Mr. Emme to state that another paper by Mr. Hall is classified but the contents are such that they would be more useful in the NASA historical program than the material presented by Mr. Hall at Boston.

4. Please advise Mr. Emme of the decision.

WARD M. MILLAR, Lt Colonel, USAF
Director of Information

11 Jan -
Karen
read me the
old letter.

Lockheed
MISSILES
& SPACE
COMPANY

2 3 DEC 1966

December 19, 1966

Mr. Eugene Alberts
Security Officer
Space Systems Division
Air Force Systems Command
El Segundo Blvd.
Los Angeles, Calif.

Dear Gene:

As per my telephone discussion with you, I am enclosing and referring to you the letter from Eugene M. Emme, NASA Historian, requesting the complete copy of R. Cargill Hall's paper on the Agena presented at the AIAA meeting in Boston on Dec. 2, 1966.

Mr. Emme's letter was addressed to R. R. Kearton, vice president and general manager of the Space Systems Division, Lockheed Missiles & Space Company.

You may be communicating directly with Mr. Emme. At any rate, we will abide by your determination as to the handling of the classified portions of the original paper.

Sincerely,

Rock Hollands

Rockwell Hollands
Manager, Public Information

RH:el
Enc.

cc: E. M. Emme
R. R. Kearton

A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION

SUNNYVALE, CALIFORNIA

LMSC/A850195

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

IN REPLY REFER TO: EH

December 6, 1966

DEC 12 08 24 '66

Mr. R. R. Kearton
Vice President and General Manager
Space Systems Division
(Mail Box 504)
Lockheed Missiles and Space Co.
Sunnyvale, California

Dear Mr. Kearton:

We were most impressed by R. Cargill Hall's excellent paper on the Ageno Booster/Satellite given on December 2, 1966, at the AAIA Convention in Boston. The Agena is a very important chapter in the history of the U. S. space program.

We would like a complete copy of Mr. Hall's paper for the permanent retention of the NASA Historical Archives. Hopefully, the complete paper might be declassified so that it would be more useful in early NASA histories such as the Gemini and Ranger histories presently underway. If it cannot be declassified, we would appreciate a complete copy, however sensitive, which will be appropriately handled as necessary.

Thanking you for your attention, I am,

Yours sincerely,

Eugene M. Emme

Eugene M. Emme
NASA Historian
Office of Policy Analysis

Distribution by M. Duren D/67-12 2-8512

R.R. Kearton	60-01/104	
J.W. Plummer	60-01/104	
R.R. McKirahan	67-01/104	
J.B. Riffel	24-01/101	Action
C.F. Hagenmaier	60-31/104	
R.C. Hall	67-20/104	
J.R. Hollembeak	67-20/104	

Reg Corr 2/102

DISPATCHED DEC 13 1966 SS Management Correspondence LMSC

[redacted]

Lockheed

MISSILES
& SPACE
COMPANY

LMSC/583531

November 23, 1966

Subject: Clearance of Technical Paper

To: Hq., SSD
Attention: Gene Alberts (SSEA)
Air Force Unit Post Office
Los Angeles, California 90045

Enclosure: (a) One (1) copy of a technical paper entitled "The Agena Satellite"

1. Enclosure (a) was prepared by Mr. R. Cargill Hall of Lockheed Missiles & Space Company.

2. Enclosure (a) is the final revised version of a paper by the same name originally submitted for your review October 19, 1966 under our LMSC number 583322. This draft is revised to conform with the instructions given us by SSD.

3. This paper is to be presented at the History Committee Session on December 1, 1966 at the Third Annual AIAA Meeting to be held in Boston, Massachusetts. This paper will also be printed and distributed through the AIAA.

4. Enclosure (a) is submitted for your review and clearance prior to release.

5. Lockheed Missiles & Space Company has tentatively determined that this material is unclassified, technically accurate, suitable for release and requests confirmation of this status. The material identified herein should be handled in accordance with the procedures established for CONFIDENTIAL information until final determination as to classification is made by the appropriate military authority.

Very truly yours,

Rock Hollands

Rockwell Hollands
Manager, Public Information

RH:blc

[redacted]

"If enclosures are withdrawn or not attached the classification of this correspondence will be cancelled in accordance with Paragraph 25a of Air Force Regulation 205-1."

A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION

SUNNYVALE, CALIFORNIA

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE SYSTEMS COMMAND
ANDREWS AIR FORCE BASE, WASHINGTON, D.C. 20331

REPLY TO ATTN OF: SCES 66-2073

2 December 1966

SUBJECT: Clearance of Paper

TO: Lockheed Missiles & Space Co.
P. O. Box 504
Sunnyvale, California

SSD SSEH-0879

IDENTIFICATION: Paper, "The Agena Satellite" by R. Cargill Hall, proposed for presentation at the AIAA Meeting, 2 December 1966, Boston, Mass.

Review of the material described above has been accomplished.

Public release is:

Approved XX.

Approved as amended on copy ____

Disapproved for reasons indicated below: ____

Sincerely

BEN R. FERN
Chief, Security Review/
Industry Relations Office
Office of Information

1 Atch
Paper (1 cy)

Copy to:
SSD (SSEA) - Ltr only

Copy to: SSD (SSEA), AF Unit Post Office, LA, Calif.

FORGING MILITARY SPACEPOWER

Lockheed Missiles & Space Co
P. O. Box 504

HEADQUARTERS
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
Andrews Air Force Base
Washington 25, D.C.

REPLY TO ATTN OF: SCES 66-2073 — 29 November 1966

SUBJECT: Security-Policy Review

TO: Secretary of the Air Force (SAFOI-S)
Washington, D. C.

IDENTIFICATION: Paper entitled "The Agena Satellite" by R. Cargill Hall, proposed for presentation at the AIAA Meeting, 8 December 1966, submitted by Space Systems Division for Lockheed Missiles and Space Co.

1. The attached material, described above, is forwarded for security-policy review.

2. Headquarters AFSC has reviewed it, has determined that it is technically accurate, unclassified and requests authority for public release.

3. To meet our suspense date for returning the material to the originator, it is requested that it be returned to AFSC, Office of Information [redacted].

FOR THE COMMANDER

BEN R. FERN
Chief, Security Review/
Industry Relations Office
Office of Information

1 Atch
Paper (4 cys)

Copy to:
SSD (SSEA)

Copy to: SSD (SSEA), AF Unit Post Office, L.A., Calif.

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS SPACE SYSTEMS DIVISION (AFSC)
AF UNIT POST OFFICE, LOS ANGELES, CALIFORNIA 90045

REPLY TO
ATTN OF: SSEA

[illegible] Nov 66

SUBJECT: Review of Material for Public Release

TO: AFSC (SCES)
Andrews AFB
Wash 25, D. C.

1. The attached material "[illegible]", has been reviewed by the Systems Program Office [illegible], the Systems Classification and Security Division and the Office of Security Review.

2. This headquarters has determined the material to be technically accurate, unclassified and consistent with program policy (as amended).

3. Request your office forward to (DOD, SAFOI, NASA, JFT-8 or AEC) as appropriate for security/policy review.

4. Further request that the originator be directly notified of releasability status and a copy of the decision, using reference SSEA [illegible], be concurrently sent this Headquarters.

5. This material is intended for [illegible] at the [illegible] meeting on Friday, December 2.

[illegible], Lt Col, USAF
Director of Information

Atch
[illegible]

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS SPACE SYSTEMS DIVISION (AFSC)
AF UNIT POST OFFICE, LOS ANGELES, CALIFORNIA 90045

REPLY TO ATTN OF: SSEA

25 Nov 66

SUBJECT: Review of Material For Public Release

TO: Lockheed Missiles & Space Company
ATTN: Rockwell Hollands
Sunnyvale, California 94087

1. The following material submitted to this headquarters for review on 19 Oct 66 has been determined to be (~~unclassified~~)(~~classified~~) unclassified Sensitive). "The Agena Satellite"

2. This Headquarters objects to its public release for the following reason : It is considered to be inconsistent with DOD Directive 5200.13.

WARD M [illegible], Lt Col, USAF
Director of Information

Atch

SSEA-0774

[redacted]

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS SPACE SYSTEMS DIVISION (AFSC)
AF UNIT POST OFFICE, LOS ANGELES, CALIFORNIA 90045

REPLY TO ATTN OF: SSEA/Gene Alberts/30302 — 20 Oct 66

SUBJECT: Request For Review of Material For Public Release
LMSC 583322

TO:

STAFF SECTION	SUSPENSE
SSVA	3 Nov 66
SSIS	10 Nov 66
SSEA	

1. The attached (news release) (news photo) (advertisement) (speech) (technical paper) (abstract only) (brochure)
"The Agena Satellite"
is forwarded for review prior to public release.

2. Request that listed offices review the material for technical accuracy classification and offer any comments pertaining to its suitability for release. In the event words, sentences or paragraphs are classified, those portions which are classified will be bracketed in RED and the classification will be noted in the margin. Such items also will be noted in the reply. Changes for technical accuracy will be marked in any color other than RED and noted in your reply. Adherence to the suspense date listed is requested.

3. If in the judgment of the reviewing officers, another unlisted SSD office should review the material, the paper should be sent that office prior to forwarding to the next listed office.

4. Public Information policy review will be performed by SSEA prior to release of subject material (or forwarding to a higher headquarters, if necessary).

5. It is desired that this material be handled as classified information until final classification has been determined.

6.

WARD M MILLAR, Lt Col, USAF
Director of Information

Atch
Tech Paper

When inclosures are withdrawn the classification of this lett will be downgraded to Uncl in accordance with AFR 205-1.

SSEA-0774

[redacted]

AGENA HISTORY

THIS IS NOT APPROVED FOR PUBLIC RELEASE

20 OCT 1966

THE AGENA SATELLITE

R. Cargill Hall

Lockheed Missiles & Space Company

Space Systems Division

DISAPPROVED FOR PUBLIC RELEASE

November 1966

20 OCT 1966

THE AGENA SATELLITE

R. Cargill Hall

Lockheed Missiles & Space Company

Space Systems Division

November 1966

Valuable

INTRODUCTION

At the turn of the twentieth century there existed very limited information concerning rocket technology, and virtually no technical information regarding astronautics. Within forty years, however, the long-range[1] ballistic rocket was fast approaching operational status as a weapon in the hands of the Germans. The subsequent appearance of this device during World War II set in motion a number of events; it upset many firmly held beliefs that inherent problems in propulsion and guidance precluded the construction of such vehicles, and it created an environment in which a vast new branch of science, engineering and industry has swiftly developed in widely separate countries. The ballistic rocket, moreover, has sharply altered the concepts of warfare as well as providing mankind with the capability to pursue the direct physical investigation of the cosmos.[2] There no longer appears reason to doubt that rocketry and astronautics will contribute to continued profound change in the course of human history.

Among the numerous events that comprise the mosaic of discovery and applied refinements in rocketry and astronautics in this country after

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[1]A range in excess of modern artillery, with reliable accuracy.

[2]A major distinction between rocketry (science related to non-air-breathing pyrotechnic devices propelled by hot gases) and astronautics (science related to manned or unmanned navigation and exploration of outer space) remains that the former technology was developed and first applied primarily as a means of advanced warfare, whereas the latter has been, by and large, directed towards more peaceful pursuits. The rocket, nevertheless, is an integral part of astronautics for it functions as the booster

the Second World War is development of the Air Force Agena satellite. The first Agena for the Discoverer Program was launched into polar orbit from Vandenberg Air Force Base in California on February 29, 1959. This event, which followed initial Russian and American satellite flights by more than a year, passed relatively unnoticed. It was, nevertheless, a significant milestone, marking the first heavy, stabilized, platform ever placed in orbit by the United States designed to provide a capability for payload recovery from space--a most ambitious step in the formative months of the Space Age--and it climaxed more than a decade of unpublicized Air Force satellite studies and development efforts that predate all other contemporary American satellite programs.

Since its first flight in 1959, Agena applications in various space programs, such as Gemini redezvous and docking, have brought this spacecraft national and international recognition. Still, knowledge of Agena's historic antecedents and early development, restricted by the unpublicized character of the work to small groups which participated directly in the original programs, has remained largely unavailable to the public and to major segments of the aerospace community. As a step to providing additional knowledge of this important story, this paper will investigate the origins and trace development of the Air Force Agena within a context of innovation in aerospace technology, treating the Agena booster/satellite as a distinct space system independent of its specific space missions.

ORIGINS OF THE AGENA SATELLITE

The first formal studies of earth satellite vehicles made with government funds in the United States were begun by the Navy and the Army Air Force several months after the conclusion of World War II.[3] These efforts, however, which might have culminated in the launching of earth satellites by the early 1950's, were undertaken at an inopportune moment in time: in 1945-46 the United States was sole possessor of atomic weapons and global air supremacy, and wartime military and civilian programs were subject to a return to "normalcy." America's return to peace time operations, the absence of international political tension that often acts to stimulate technological advance, and residual opinion still shared by many that construction of intercontinental rockets was infeasible[4] were to preclude the Navy and Army Air Force satellite proposals from commanding active support in the highest echelons of the War Department.[5] While neither of these early satellite proposals received a green light for development at this time, the Army Air Force studies became the matrix from which the Agena satellite derives its origins.

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[3]For a comprehensive review of these earth satellite studies conducted during the 1940's, see R. Cargill Hall, "Early U. S. Satellite Proposals," The History of Rocket Technology, E. M. Emme ed. (Detroit: Wayne State University Press, 1964).

[4]Dr. Vannevar Bush, for one, Director of the Office for Scientific Research and Development, and Chairman, Joint Committee on New Weapons of the Joint Chiefs of Staff (1942-1946), told a Special Senate Committee on Atomic Energy in December, 1945, that development of a long-range high-angle rocket (of the type needed to put a satellite in orbit) "is impossible and will be impossible for many years . . ." Inquiry Into Satellite and Missile Programs, Part I, Preparedness Investigating Subcommittee, Senate Committee on Armed Services, 85th Congress, 1st and 2nd sessions, November 1957-January 1958, p. 283.

[5]Prior to 1947, the Department of Defense (and a separate Air Force) had not been established.

Air Force Satellite Feasibility Studies

In March 1946, the Army Air Force commissioned Project RAND[6] to prepare an engineering analysis of the possibilities of designing a man-made satellite. This decision was prompted by the study of a single-stage satellite rocket inaugurated earlier by the Naval Bureau of Aeronautics in late 1945, and RAND was directed to produce its feasibility study in three weeks because the Air Force and Navy were scheduled to present their respective cases for unmanned satellites before the next monthly meeting of the Aeronautical Board of the War Department.[7] With interservice competition in the new field of astronautics formalized in the early months of 1946, these separage satellite studies soon assumed the character of programs undertaken to demonstrate to the War Department that one or both of the two services had a feasible satellite program, and thus might lay claim to weapon developments in the medium of space.

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[6]Project RAND was established in late 1945 and initially operated as a semiautonomous branch of the Douglas Aircraft Corporation, responsible directly to the Vice President, Engineering. Qualified physicists, engineers, and mathematical analysts were drawn from Douglas and other aircraft firms, and assembled at Santa Monica in separate quarters. The original concept was that several companies would get together and set up an advisory type function which, in turn, would allow RAND to advise the various services on what they should procure, so that the services would not request the "impossible" from industry in the area of aircraft armaments. In November 1948, the RAND Corporation was created and became a completely autonomous non-profit research institution.

[7]The Aeronautical Board, formed during World War II, was composed of representatives from the Army and Navy Air Forces to review new developments and coordinate similar requirements for the two air corps. Later in 1946 this organization was supplanted by the Joint Research and Development Board (JRDB) of the War Department which expanded and formalized the functions pefformed by the Aeronautical Board, and was responsible for the preparation of an integrated program of research and development in the light of which individual projects of the Army,and Navy could be evaluated.

On May 12, 1946, twenty copies of the RAND document entitled Preliminary Design of an Experimental World-Circling Spaceship were delivered to the Air Materiel Command at Wright Field in Dayton, Ohio. Having carefully analyzed the state-of-the-art and potential developments, the men working at Project RAND asserted that "technology and experience have now reached the point where it is possible to design and construct craft which can penetrate the atmosphere and achieve sufficient velocity to become satellites of the earth."[8] This conclusion was well documented in the RAND report which, admittedly, was a feasibility design study of a satellite vehicle "judiciously based on German experience with the V-2," and which relied for its success on "sound engineering development which could logically be expected as a consequence of intensive application to the effort."[9] The achievement would be realized by advances in engineering that would permit, for example, greater pressures and temperatures in lightweight structures, and was not dependent upon a scientific breakthrough as in the case of development of atomic weapons.

One of the important conclusions of this RAND study was that it would be highly advantageous to employ a multi-stage rocket utilizing given types of liquid propellant in order to achieve required performance. Analysis of the propellant combinations for staged vehicles revealed that four stages were optimum for conventional fueled liquid alcohol-oxygen rockets,

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[8] Preliminary Design of An Experimental World-Circling Spaceship, RAND Report No. SM-11827, Contract W33-038 ac-14105, May 2, 1946, p. 1.

[9] Ibid.

and three stages were determined optimum for a liquid-hydrogen-oxygen rocket. Although construction and launch of a satellite was deemed feasible with existing technology (it was felt that a 500-pound satellite could be placed on a 300-mile orbit within five years, or by 1951), Project RAND ruled out the satellite as a military weapons carrier. Here the status-quo of military utility was to remain for some years. The problem was not a lack of wherewithal to orbit a satellite vehicle, but rather that of devising a useful function for the satellite to perform once it was in orbit.

To establish a case for development of a satellite vehicle the report summary chapters went into some detail on potential para-military uses for such a device including astronautical observation of cloud patterns, observation of the earth, short-range weather forecasting, as well as biological observation in a gravity-free environment. Heavy emphasis was placed on the possible use of the satellite as a communications relay station. A man-made satellite had been determined a feasible device, but not a military weapon. Because it was not a weapon funding was not readily available, for traditionally in military budget allocations, strategic systems tend to enjoy the greatest priority, tactical systems next, defense systems third, and a very poor fourth, all support systems such as those proposed for the earth satellite.

Following the Navy and Army Air Force satellite presentations in June 1946, the Aeronautical Board arrived at a decision to let the services pursue their independent studies separately and postponed any jurisdictional assignment for the medium of space.[10] The Navy satellite effort, which had received authorization to proceed from the Chief of Naval Operations in May 1946, continued their investigation with the state purpose of contributing "to the advancement of knowledge in the field of guided missiles, communications, meteorology, and other technical fields with military applications."[11] The Navy Study of a proposed liquid hydrogen-oxygen single-stage satellite rocket was to continue through mid-1948, conducted by the structures division in the Navy Bureau of Aeronautics and under a joint contract by Glenn L. Martin--Baltimore Company and Aerojet, in addition to a structural study conducted by North American Aviation.[12]

Project RAND also commenced a second study in mid-1946, directed toward preparing more detailed specifications which would set forth minimum requirements for achieving a successful satellite vehicle. This work was completed in late 1946, and the reports were published in February 1947. Results of this second RAND study, which was actually a refinement of the World-Circling Spaceship, indicated a need for additional research and development in several vital component areas; certain subsystems had to be further perfected before a realizable satellite system would operate

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[10]From a transcript of an interview with Dr. Harvey Hall, March 21, 1963.

[11]Eugene M. Emme, Aeronautics and Astronautics, 1915-1960, Washington, D. C., 1961, pp. 51-52.

[12]The structures study conducted by North American Aviation investigated the feasibility of design and construction of a single-stage liquid hydrogen-oxygen satellite rocket with a high fuel-to-structure mass ratio. See Structural Design Study, High Altitude Test Vehicle, Contract NOa(s)-8349, North American Aviation Incorporated, Report No. NA 46-758, September 26, 1946; and Pedro C. Medina, High Altitude Test Vehicle Summary Report, Glenn L. Martin Company, Engineering Report No. 2666, June, 1947.

satisfactorily. As noted previously, at no time was there a lack of confidence in available talent or materials for building air frames or developing rocket engines and guidance systems that would be sufficient to put something on orbit. Rather, the areas which required further refinement were those which would make that something useful and not simply amount to blasting rocks into orbit. Several of these significant areas were guidance and flight-control, orbital attitude control, ground-space communications techniques and equipment, and dependable auxiliary power sources.

When the second Project RAND study was published in early 1947, the Army Air Force was preparing to reorganize as a separate service under the National Security Act, which became law on July 26, 1947. The National Establishment replaced the War Department on September 17, 1947, and the new cabinet post of Secretary of Defense was created. Decisions as to which service would have jurisdiction for development and deployment of long-range rockets were postponed by the Research and Development Board. (RDB).[13] None of the three services was immediately authorized to further the development of long-range ICBM-type rockets needed to put a satellite into orbit.

As a consequence of severe economies in the Military research and development program directed by the Administration in December 1946, and the lack of a firm jurisdictional assignment for long-range rockets, the Air Force/RAND satellite effort, which had progressed through production

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[13] The JRDB was reorganized as the Research and Development Board under the Department of Defense. Dr. Vannevar Bush was appointed its first chairman.

of design specifications in early 1947, came to a virtual halt. From mid-1947 until mid-1948 only the Navy Bureau of Aeronautics continued intermittent satellite research activity. The Air Force discontinued work on the satellite and ICBM programs and placed primary emphasis on strategic bombers and air-breathing ram or pulse-jet guided missiles which operated in the atmosphere and were, therefore, legitimately within Air Force jurisdiction. About the time the Navy satellite study program was terminated for lack of funds, the Air Force satellite study program recommenced in 1949; in part this was due to advances in guidance and control and the miniaturization of some hardware made by U. S. industry while working on other rocket programs, and in part due to new directions received from the Research and Development Board.

Air Force Satellite Mission Definition Studies

A review of the contemporary Navy and Air Force satellite programs was conducted by the RDB in March 1948, and, although the Board did not authorize or assign a formal program to any organization, the services were encouraged to pursue further studies on the military and scientific utility of satellites that would justify expenditure of funds necessary to develop spacecraft.[14] Shortly thereafter the RAND Corporation was given responsibility by the Air Force for continuing studies of the potential military utility of earth satellites--including work on the use of such devices for cold-war politico-psychological advantage, for

[14] Dr. Harvey Hall, "Early History and Background on Earth Satellites," ONR:405:HH:dr, November 29, 1957, p. 4.

communications, and for purposes of observation--and to recommend appropriate development programs.

Among the satellite utility investigations which commenced early in 1949 was a conference on the psychological effects of earth satellites sponsored by the Social Science Division at RAND. The conference, attended by noted scholars that included Harold Lasswell of Yale and Ansley Coale of Princeton among others, arrived at the general conclusion that satellites could be employed as an "instrument of political strategy" if the surveillance capacity of the vehicle were exploited in a manner "designed to register maximum impact upon the leaders of the Soviet Union."[15] In the event a satellite was employed as a surveillance instrument which could penetrate the enforced secrecy behind the iron curtain, and the information acquired by the satellite was subsequently disclosed overtly or covertly, then, it was hoped, confusion, recrimination, and possible purges might result in the Soviet hierarchy.

At the termination of the study conference specific recommendations were made to the parent RAND Corporation that (1) the Air Force be appraised of the opportunity afforded by the surveillance potential of a satellite vehicle, and (2) the United States, at the highest policy level, be informed of the unique political/psychological opportunities provided by this non-violent instrumentality. RAND, which organized the study conference primarily as an exploratory method for review and analysis of the

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[15] RAND Research Memorandum RM-120 (Preliminary Report No. D-387), "Conference on Methods for Studying the Psychological Effects of Unconventional Weapons," February 3, 1949.

psychological effects of unconventional military devises, took these conclusions and recommendations under consideration. Implementation of a satellite program to exploit its psychological impact was never undertaken; however, emphasis remained attached to a passive surveillance application when RAND began serious component studies and designs for an earth satellite.

The secrecy that attended military satellite studies in these early years prevented knowledge of this work from being widely disseminated. A veiled announcement of the Earth Satellite Vehicle Program contained in the First Annual Report of the Secretary of Defense in 1948 caused a great deal of consternation among those working on the project in the United States, and drew caustic remarks from the Soviet press.[16] A security leak two years later, following assignment of jurisdiction for space satellites, allowed a syndicated columnist to break the story of military satellites in the popular press for the first time. Stewart Alsop, after commenting at length on the mechanics of the satellite problem and probable mission objectives, asserted that "all this is no mere fantasy. The scientists who have been studying the project warn that it is not to be treated as 'science fiction' but as a perfectly practical matter given the necessary time and money." He concluded: "In the end, President Truman will order work started on this fantastic project if only for an old familiar reason--if we don't, the Russians will."[17] After this

[16] R. Cargill Hall, op. cit., p.

[17] Stewart Alsop, "Man-Made 'Moon' Serious Project," Washington Post, Sunday, August 13, 1950.

announcement little more was heard of actual satellite programs in open literature until the American IGY satellite programs commenced in 1955. It was then, apparently, still too fantastic a concept and strained public credulity, and no one was willing to credit Russian technology with that kind of capability.

A major change in the status of military satellite effort occurred on 15 March 1950, when the Joint Chiefs of Staff recommended assignment of exclusive responsibility for long-range strategic missiles to the Air Force. This assignment was confirmed a few days later on 21 March by Secretary of Defense Louis Johnson. Concurrently, the RDB vested satellite custody with the Air Force. With jurisdiction assigned, the Air Force directed RAND to intensify exploration of satellite military utility. In late 1950 RAND recommended an expanded study of satellite surveillance applications to the Air Staff and, upon authorization to proceed, published a formal report in April 1951.[18]

RAND's 1951 report <u>Utility of a Satellite Vehicle</u> (R-217)[19] considered in detail the use of an earth-circling spacecraft as an earth observation platform and concluded that ". . . no radically new developments are indicated, however; rather, a reconstitution of known theory and art in rocketry, electronics, engines and nuclear physics."[20] A two stage

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[18] Air Research and Development Command, <u>Space System Development Plan</u>, Secret report No. WDPP-59-11, January 30, 1959, Tab I, "Background," p. I-1-1.

[19] RAND "Utility of a Satellite Vehicle," R-217, April, 1951, declassified.

[20] Ibid., p. 80.

hydrazine-liquid oxygen-propelled rocket, 55 feet in length and weighing 74,000 lbs. gross at launch, was proposed for the mission requirements. The reliability of satellite components, particularly electronic subassemblies which had to withstand initial acceleration and vibration and then function properly in the rigors of a free space environment, was considered to be the limiting factor in the overall effectiveness of the proposed mission.

Following publication of the satellite utility report the Air Force awarded a number of study contracts to industry to examine specific satellite subsystems. These included the payload, Radio Corporation of America; guidance and attitude control, North American Aviation; and auxiliary power, Bendix Aviation, Allis-Chalmers, Vitro Corporation, and Westinghouse Electric Corporation. The results of these studies, conducted between 1951 and 1953, were encouraging and, in November 1953, RAND recommended development of a satellite program and concluded its work by publishing a final report in March 1954.[21]

The Project Feed Back Summary Report (R-262)[22] of 1954 described a military support mission for a space satellite and outlined a typical

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[21] Space System Development Plan, loc. cit.

[22] RAND Project Feed Back Summary Report, ed. by James E. Lipp and Robert M. Salter, R-262, March 1, 1954, Vols, I and II, Contract No. AF 33(038)-6413. (Documents are now classified Confidential.) Included is a complete roster of personnel who had engaged in the Air Force satellite studies since 1946, and a bibliography of study documents and progress reports. The code name "Feed Back" was selected over a proposed code name "Man Hole" because it was not easily mispronounced and because a two-word code name indicated that the project was classified whereas a one-word code name meant that the name as well was classified. Later Robert Salter recollected that when the teletype was first received from the Department of Defense with the new code name project "Feed Back," the print-out had a typographical error and read "Feed Bag," much to the amusement of those engaged on the program.

example of hardware necessary to accomplish the task. The two-stage rocket proposed for the mission was 81 feet in length overall and 9 feet in diameter, the length of the satellite stage being 28½ feet. Gross weight at launch was about 178,000 lbs. with the satellite stage comprising 22,500 lbs. gross and an orbiting weight of 4,500 lbs. Based on contemporary propulsion technology, power was to be supplied by engines burning gasoline and liquid oxygen. A single fixed engine of 36,000 lb. thrust was proposed for the second stage, with jet vanes employed for control of the flight trajectory during engine burn. Methods for guidance and orbital attitude control and auxiliary power also were included. An illustration of this RAND satellite design, the immediate precursor of the Agena, is shown in Figure 1.

RAND reiterated that design and development of a satellite vehicle "will not require radically new technology or enormous cost," and concluded that "complete development and initial operation can be accomplished in about 7 years for a cost of the order of $165 million. This cost figure is believed reliable within a factor of two. . . . Cognizance is now being turned over to the Air Force with the recommendation that the program be continued on a full-scale basis."[23]

The year 1955 marks crystalization of collective thinking within the Department of Defense to proceed with development of a satellite possessing military utility. On November 27, 1954, eight months after publication of the Project Feed Back Summary Report, the Air Research and Development Command (ARDC) issued System Requirement No. 5 to implement

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[23]*Ibid.*, Vol. I, p. vii.

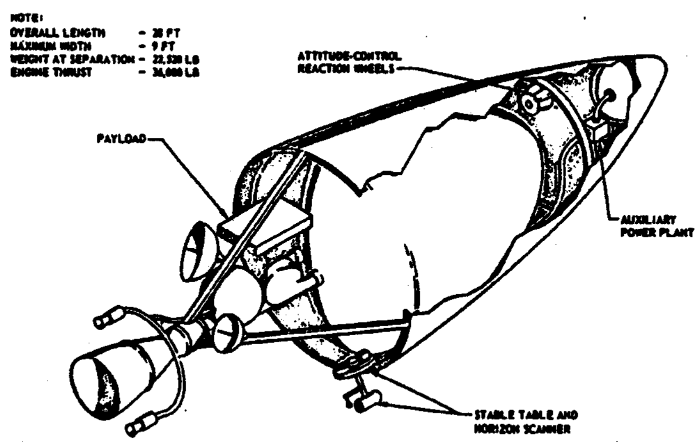

Fig. 1 Satellite Vehicle Proposed by RAND, 1954

a satellite program through system design studies and a development program. The Air Force subsequently released General Operational Requirement No. 80 (SA-2c) on March 16, 1955, which established the formal requirement for a strategic satellite system.[24] Resultant action was solicitation from industry of design study proposals for the military satellite. A small group of companies were chosen to participate: Radio Corporation of America, the Glenn L. Martin Company, and Lockheed Aircraft Corporation. Bell Telephone Company, which was invited to engage in the competition, declined to participate. Award of the design study contracts marks the formal beginning of the Air Force Agena satellite program.

DESIGN AND DEVELOPMENT OF THE AIR FORCE AGENA SATELLITE

Astronautics technology still existed almost completely in theory expressed in paper documents when contracts for the WS-117L (Air Force Satellite Program) design study competition were awarded in 1955. The Atlas ICBM and Thor IRBM, which were later employed as first stage boosters for the Agena, had not yet progressed to test flights. A small amount of hardware, primarily of a laboratory nature for use in large ballistic rockets and the proposed satellite program, was just coming into existence.

Controversy over certain technical aspects of rocketry and astronautics surrounded these proposed programs in the Department of Defense. Professional opinion remained divided on the possibility of developing the pure ballistic rocket, like the Atlas, in large sizes of intercontinental range, and the subject of liquid-propellant rocket engine performance in a vacuum was subject to vociferous debate. Many experts believed that without

[24] Lockheed Secret Report LMSC/447999, Satellite Systems History, Vol. I, Section 1, "Historical Background," 1962, p. 1.0-8.

adequate chamber pressure a turbo-pump liquid-propellant rocket engine would not ignite in the vacuum of space. (This debate accounted for the peculiar staging of the Atlas ICBM which eliminated this difficulty by igniting all its engines at liftoff.) Although the feasibility of powered flight in space was now accepted, turbo-pump rocket engine ignition in a vacuum had not been demonstrated.[25] In this milieu design and development of the Agena satellite began.

Prior RAND studies and proposed mission objectives imposed highly refined predetermined technical requirements for the Air Force satellite; it was to be a relatively large second-stage vehicle capable of (1) obtaining a precise, predicted, earth orbit, (2) stabilizing on three axes with a high pointing accuracy, (3) maintaining a given attitude and compensating for disturbing torques, and (4) receiving and executing commands sent from the ground, and transmitting information to ground receiving stations. Later the requirement to eject research payload capsules from orbit for recovery on the earth's surface also was introduced. Design and development of the Agena to achieve these objectives falls into three principle periods: satellite design study, engineering and operational development, and recent innovation.

Air Force Satellite Design Study Competition

Company-funded study of earth satellites began at Lockheed in late

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[25] Vanguard and Explorer, America's first programs to orbit earth satellites, avoided this potential problem by employing solid-propellant and pressure-fed liquid-propellant rockets for their upper stages.

1954, shortly after the newly-formed Missiles System Division,[26] quartered Van Nuys, California, entered the Air Force procurement competition for the secondary source ICBM.[27] Robert Salter, the Lockheed proposal leader on the ballistic rocket program, advanced the satellite study effort on his own initiative based on extrapolation of potential performance of the secondary source ICBM and his prior experience in the field of astronautics at the RAND Corporation. At first objections to the proposed independent satellite studies were raised because astronautics technology was undeveloped, and because there was not a large dollar return evident on the work; however, the thinking of Salter and his associates prevailed and the company assigned several personnel to divide their time between the ICBM proposal and earth satellites.

Contact was established with the Air Research and Development Command at Wright Field and subsequently, in February 1955, Lockheed accepted the Air Force invitation to compete in the earth satellite procurement competition.[28] Air Force-funded research and development commenced

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[26]Formed in late 1953 as a corporate entity, the Lockheed Missiles System Division (LMSD) began work in January 1954 with 175 employees and a $400,000 backlog of orders from a previous ramjet program. The Division outgrew the Van Nuys facility and moved to new quarters at Sunnyvale, California in 1956. LMSD was changed to Lockheed Missiles and Space Company (LMSC), a wholly owned subsidiary of Lockheed Aircraft Corporation, in June 1961. In this paper it is, hereafter, referred to simply as Lockheed.

[27]Later won by the Glenn L. Martin Company, this two-stage tandem ICBM is now known as the Titan.

[28]<u>Request for Proposal on Purchase 175626</u>, Wright Air Development Center, Air Research and Development Command, Dayton, Ohio, Secret Report No. 54WCS-15180, 15 February 1955.

the following month, coincident with release of General Operational Requirement No. 80, when one-year study contracts were awarded to Lockheed, Glenn L. Martin Co., and RCA.[29]

The research and design study program conducted during the ensuing year evaluated the possibilities of achieving the specified program objectives, and it established the direction and magnitude of the technical programs required to realize development. Lockheed system design studies proceeded beyond earlier RAND efforts (which had examined what subsystems and equipments were necessary in creating a satellite and discussed and analyzed the overall system), and evaluated what existing equipments could be readily adapted, and what equipments required additional refinement to meet the program requirements.

Although satellite mission objectives and technical parameters were established at the outset, initial design analysis took place without Air Force specification of exactly what rocket would be employed as a first stage booster. As a consequence studies progressed utilizing various weights and dimensions to meet various possibilities even though the Atlas was considered to be the most logical candidate. In January 1956, the competing contractors were formally notified that the Atlas SM-65 Series "C" booster, under development at Convair Astronautics, would be used to launch the Air Force satellite.

Convair Astronautics informed all contractors that the maximum weight the Atlas would carry was 3500 pounds. Lockheed performed a dynamic analysis based on available performance characteristics and found that the

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[29] Air Force Letter Contracts AF 33(616)-3105, -3106, and -3104 respectively.

1½ stage Atlas would carry nearly 10,000 pounds, and up to 15,000 pounds if Convair would agree to strengthen the forward end of the booster with a girdle. Convair turned down this suggestion due to Atlas requirements to perform as a ballistic missile, and Lockheed consequently completed its "design of a satellite and all of the subsystem to match any probability for the gross weight which might finally be agreed upon."[30] In its final report, Lockheed offered studies based on both a "Pioneer" vehicle weighing 3,500 pounds and an "Advanced" vehicle weighing 7,800 pounds at separation. Utilizing its initial design work, Lockheed also postulated employing an XBM of intercontinental range for achieving an earlier orbital capability, and this latter study ultimately allowed for the rapid adaptation to the Thor booster when it was injected into the program in early 1958.

The final Lockheed Pied Piper Development Plan submitted under the study contract in March 1956, asserted that "the vehicle system that has evolved incorporates no major deviations from the present state-of-the-art and the limited development necessary presents no unusual technical problems."[31] Four ground rules were proposed to guide development:

> The first ground rule reduces the hardware selection problem to a matter of availability.
>
> The second ground rule limits the size and design weight of the orbiting vehicle, and it also imposes the major structural design criteria for all structure of the orbiting vehicle with the exception of the tanks; e.g., the height of the gantry crane would limit length.

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[30] Interview with Mr. P. L. Taulbee, 15 November 1961.

[31] Lockheed Secret Report No. 1536, Pied Piper Development Plan, Vol. II, Subsystem Plan, A. Airframe, A-Apdx, 1 March 1956, p. 3.

The third ground rule was adopted on the basis of insurance for achieving orbit even if booster performance is 30% below par. It is reasonable to assume such booster degradation in the early firing phases of the Atlas program, ~~but the figure is probably 30% pessimistic~~. Tankage used in the Pioneer vehicle is approximately three times greater than would be necessary if no booster range degradation were considered.

The fourth ground rule limits the use of solid rockets. In this connection there are problems of obtaining acceptable specific impulse, vehicle path control, and engine thrust cut-off.[32]

The configurations of the Pioneer (Agena A) and Advanced (Agena B) vehicles are basically the same--a cylindrical body and a conical nose--and appear in Figures 2 and 3. The nose cones were designed only as fairings and to provide environmental protection for the guidance and control systems. Skirt sections would remain with the booster at separation and thus expose the payload and transmitting elements without additional mechanical operations.

The diameter of the cylinder of the Pioneer vehicle was determined by the diameter of the Atlas booster, and was reduced from 68 to 60 inches. The length of this vehicle, initally postulated as high as 21½ feet, was reduced to 15½ feet which was the maximum allowable for the clearance between the Atlas booster and the gantry crane of the contemporary launcher. Nested propellant tanks were proposed together with a pressure-fed liquid rocket engine of 7,500 pounds thrust (at altitude) then under development by Aerojet-General for the Vanguard Program. Two, small, swiveling, 150-pound thrust vernier engines would be placed on either side of the fixed main engine to provide roll control, or could be deleted if the main engine were gimballed.

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[32] Ibid., pp. 3-4.

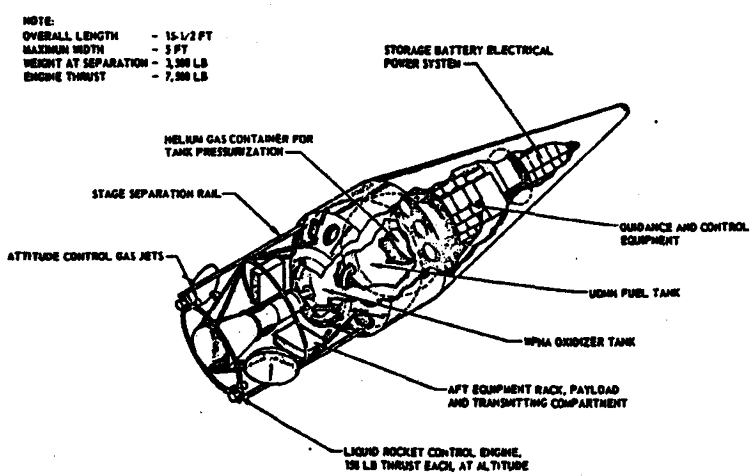

Fig 2 Pioneer Satellite Proposed by Lockheed, 1956

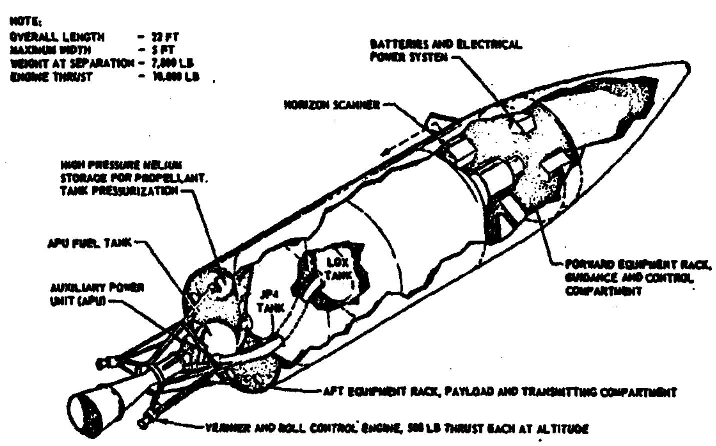

Fig 3 Advanced Satellite Proposed by Lockheed, 1956

The Advanced vehicle, proposed to meet future requirements for increased duration of operation on orbit, had a similar diameter of 60 inches and an overall length of about 22 feet. It was to be a pressure-stabilized structure, like the Atlas, with integral tanks, and use a 10,000 pound thrust (or larger) liquid-propellant turbo-pump rocket engine. Like the Pioneer, two smaller thrust vernier engines could be employed for flight control in the event the main engine was confined in a fixed position. Throughout the design study in 1955-1956, the overall length and width of the Agena satellite varied between 15 - 25 feet and 60 - 70 inches respectively. Basic subsystem developments to meet technical requirements are examined in the following section.

The Lockheed Pied Piper satellite proposal which was submitted to the Air Force in March 1956-- and which ultimately won the [redacted] design competition-- was judged an exceptionally thorough analytical study, particularly in the areas of subsystem development, in application of existing and proposed equipments, and in systems integration. The Air Force determined that a contract could be awarded to implement the proposed [redacted] satellite system, and Lockheed was notified of Air Force intent to award a contract in late June, 1956. The second phase-- engineering and operational development of the Agena-- was inaugurated with execution of the basic Letter Contract AF 04(647)-97 on October 29, 1956.

Development of the Air Force Agena

Development and first flights of the Agena A and Agena B satellites took place between 1957-1960. It was during this relatively brief period that Sputnik I ushered in the Space Age, when government policy decisions were made establishing new organizations to manage current and proposed space programs, and where, for the contractors engaged in America's space programs, the slow, often agonizing process of fabricating, flying, and perfecting functional space vehicles transpired. The Air Force satellite program was delayed in gaining a priority among advanced programs under development in the Department of Defense, but in August 1957, the Air Council approved the WS-117L program as presented by the Air Force Ballistic Missiles Division and recommended "go-ahead" as fast as possible consistent with good management. This recommendation subsequently was approved by the Secretary of Defense several months later, in November, shortly after Sputnik I was launched.

The strategic and psychological impact of Sputniks I and II introduced new urgency into American military and civilian space planning, and caused the establishment of new control agencies to "coordinate" national space activities, and the acceleration and augmentation of the WS-117L program. In January 1958 the Air Force directed that planned Agena launch dates be advanced, introduced the Thor IRBM as booster in place of the Atlas ICBM for the first ten flights, and latered the planned launch location from Cape Canaveral (now Cape Kennedy) in Florida, to Vandenberg Air Force Base (then Camp Cook) in California. The new requirements to launch early test flights on Thor into a polar orbit, rather than on the larger Atlas into a low-inclination orbit forced some alteration in the Agena design to match the configuration of the new booster and to conform to the stringent weight limitations it imposed.[33] A few months later an additional technical requirement was imposed: develop and flight-test a research payload capsule ejection and deorbit system that would permit recovery on the earth's surface.

The Air Force Ballistic Missiles Division had been given responsibility for management and technical direction of the WS 117L (Sat) program when the contract for the program was awarded in late 1956, and except for a brief interlude in 1958-1959, this assignment has remained with the Air Force. In February 1958 the Advanced Research Projects Agency (ARPA) was established in the Department of Defense and placed in charge of the nation's military space programs. (Responsibility for America's civilian space programs was vested in NASA created by the National Aeronautics and Space Act of 1958.) Cognizance for ~~WS 117L~~ technical direction was transfered to ARPA in May of that year although the Air Force retained the role of system manager. Separation of the ~~WS 117L~~ military satellite missions into individual space programs occurred in September and November 1958, at ARPA direction,[34] ~~with the Thor-boosted portion identified as "Discoverer."~~

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[33]An eastward firing from Cape Canaveral yields a velocity increment of 1000 to 1300 feet-per-second as a performance margin due to the earth's peripheral velocity. This advantage is lost in a southward firing into polar orbit, and requires a reduction in vehicle weight or larger propellant tanks and engines to gain increased velocity.

[34]ARPA Orders No. 48-59 and No. 38-59, respectively.

The name "Agena" also was selected for the Pioneer satellite at this time.[35] In September 1959, the Department of Defense reinvested technical direction of the military satellite programs in the Air Force Ballistics Missile Division, and ARPA was relegated to a research function.

The intensive analytical ground work that preceded actual design and fabrication of the Air Force Agena and the complicated technical objectives that were involved were to make this vehicle the largest and most sophisticated of the early American satellites. At the same time these requirements prevented the Agena from being first into space for the United States.[36] The First Agena A ~~completed fabrication and checkout and was~~ delivered sold to the Air Force in October 1958, the first launch was conducted successfully from Vandenberg

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[35] An ARPA special committee apparently was responsible for selecting this name in mid-1958, in keeping with Lockheed's tradition of naming iar-craft and missiles after stellar phenomenon, e.g., Vega, Constellation, Polaris, etc. The name was agreed upon after some reservations voiced at Lockheed were dropped: that the atar Agena, otherwise known as Beta Centauri, although 5000 times brighter than the Sun, was 300 light years from earth and not readily evident in the night sky. Documentation on the actual date and manner of selection of this name is missing.

[36] A few months after release of the final RAND Project Feed Back Summary Report in June 1954, an informal meeting was held in Washington, D.C. among members of the Air Branch of the Office of Naval Research, the Army rocket group at Redstone Arsenal, and several interested civilian scientists. That meeting inaugurated a chain of events that resulted in a decision by the President of the United States to authorize launch of artificial earth satellites as part of America's contribution to the Inter-national Geophysical Year in 1955, and the first American satellite, Explorer I, was placed in orbit on January 13, 1958 by the Army's Redstone rocket team. For a review of these developments, see R. Cargill Hall, "Origins and Development of the Vanguard and Explorer Satellite Programs," The Airpower Historian, Vol. XI No, 4, October 1964.

Air Force Base on February 28, 1959,[37] and the first payload successfully ejected from orbit and retrieved by recovery forces took place on August 10, 1960. Work on the advanced Agena B which incorporated larger propellant tanks and an engine restart capability commenced in June 1959, and culminated in a successful first launch on November 12, 1960.

The technical problems presented in Agena development and the engineering approaches and manufacturing techniques that were adopted to solve them provide an interesting commentary on the process of innovation in aerospace technology during the formative years of the Space Age. Development of the basic Agena A and Agena B, by subsystem, is examined below.

Spaceframe. The fundamental problems associated with development of the satellite spaceframe[38] were (1) selecting proper structural materials with which to build the Agena and establishing a process for fabricating the propellant tanks, and (2) developing a thermal control system to protect vehicle equipments from extremes of temperature. Selection of material for structural application was based upon minimum weight considerations coupled with producibility and availability during the schedule manufacturing periods.

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[37] An earlier launching was attempted on January 21, 1959 for the Discoverer Program. In the process of vehicle checkout during countdown the Agena ullage pyrotechnics ignited badly searing the Thor booster, and the planned launch was cancelled. This launch attempt was not publicized, and later became known as "Discoverer 0".

[38] In general terms, the spaceframe serves to maintain the structural shape of the vehicle, house or support the other components or subsystems, ensure necessary environmental protection, allignment, and component accessibility under the various operational conditions of transport, checkout, launch, boost, coast and orbit.

Magnesium-thorium, stainless steel, and beryllium were investigated, and the mag-thorium alloy was selected as the basic structural metal for use in all areas except the propellant tanks due to its light weight, strength, and performance under high temperature. While mag-thorium initially was considered for the skin only, new forging and sheet metal forming techniques were developed for handling this material in large quantities which permitted wider application.[39] Thorium itself is a radio-active material and also presented problems of establishing methods for working it without creating radiation hazards.

The pressurized nonintegral (with the vehicle skin) propellant tanks planned for the Agena A were designed in a rather peculiar shape in a nested position to permit holding a large volume in a short length and width, and also had to be very light in weight. Stainless Steel, titanium, and aluminum were investigated, and aluminum ultimately was employed for construction of the tanks because of its high strength to weight ratio, resistance to acid corrosion, and available techniques for working the metal. Fabrication of very thin stainless steel tanks was first attempted in an orange peel fashion using a process of continuous spot welding developed by Lockheed, and then by spinning. A uniform thickness in tank walls could not be obtained by spinning stainless steel, however, and this metal was rejected. Later, spinning of aluminum tanks was adopted which allowed for an increase in skin thickness with lighter-weight aluminum combined with continuous spot welding to join the tanks. The helium sphere was moved out of the nested tank configuration

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[39]The development of techniques for working mag-thorium later had a carry-over on the Polaris missile effort, and was of some assistance in the rapid attainment of that program.

proposed in the WS 117L Pioneer vehicle and placed on the aft equipment rack of the Agena A together with the attitude control gas vessels, as shown in Figure 4. The initial low-weight design of the Agena A and the choice of a new turbo-pump rocket engine in place of a pressure-fed engine in 1957 permitted rapid adaptation to the Thor booster without extensive redesign.

The requirement for an environmental control system for vehicle equipment was extremely critical in development of the Agena, as equipments had to be protected from the extremes of heat and cold that would be encountered in free space. Intensive studies were made of the types of coatings, compartmentalization, and heat transfer paths that could be employed. The thermal control system that resulted from these investigations was completely passive, that is, there were no heat producing sources or coolers, and environmental control was obtained by conduction and radiation with little convection conditions. This first passive thermal control system for an earth satellite was an indispensible ingredient in the satisfactory performance of the Agena on orbit, and proved to be a significant contribution to aerospace technology.

The follow-on Agena B satellites were built and first flown in the 1959-1960 period,[40] and were designed to meet expanding program objectives; they were developed from the same structural materials and fabrication processes employed for the Agena A. The Agena B, however, was lengthened amidships with new integral tanks providing a doubled propellant capacity (13,255 lbs.), embodied a modified rocket engine capable of dual burn, and afforded additional space for relocating vehicle equipments to meet various mission requirements, as indicated in Figure 5.

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[40] The last Agena B satellite was launched in the NASA Nimbus program on 15 May 1966. The last Agena A was launched in January 1961.

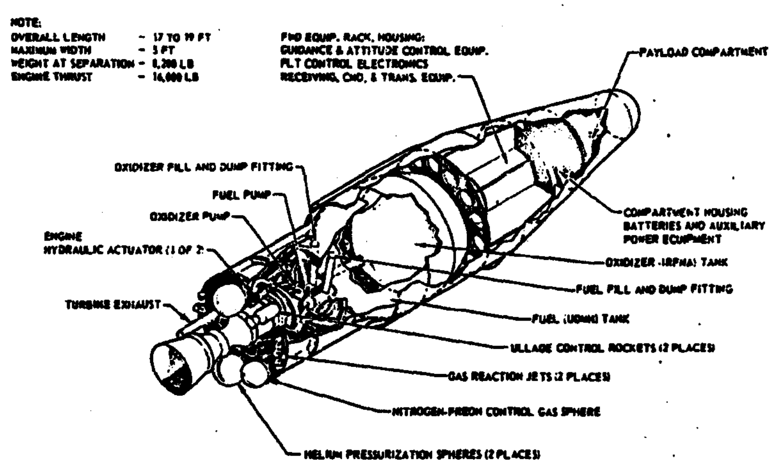

Fig 4 Agena A satellite, 1957 - 1961

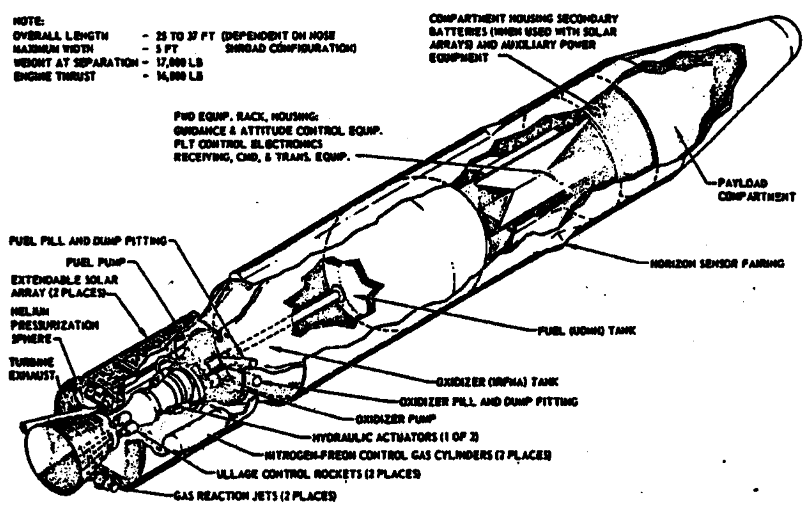

Fig 5. Agena B Satellite, 1959-1966

Propulsion. Liquid propulsion rocket engine technology was reasonably well developed when work commenced on the Agena Satellite. For Agena application, the major obstacle to propulsion system development involved making a technical decision between a pump-fed or pressure-fed liquid propellant rocket engine. In early 1957 Lockheed proposed using the Bell Hustler (8048) pump-fed rocket engine in place of the Aerojet-General Vanguard pressure-fed engine that had been originally selected.[41] The Air Force at first refused to accept this change, reasoning that (1) the pressure-fed system was much simpler, (2) the cost per-engine was lower than the pump-fed system, and (3) the pump-fed system might not ignite in a hard vacuum without modifications. Lockheed had become convinced of the merits of the higher performance Bell engine (16,000 lbs thrust compared to 7500-to-10,000 lb. thrust for the Aerojet counterpart) through the efforts of a former German rocket expert who had affiliated with the company, and argued that the pump-fed engine was the most advanced engine available, that it was more easily instrumented and could be ground-tested,[42] that it offered greater growth potential for adaptation to an advanced satellite, and that the propellant tank pressurization system was simplified in its use. In addition, engine closure was proposed to ensure ignition in a hard vacuum just in case it was required. (Closure would be

[41] Radio Corporation of America, which had proposed use of the Bell Hustler pump-fed engine, had lost the design study competition to Lockheed proposing the Vanguard pressure-fed eggine.

[42] The pump-fed engine could be tested on the ground, and a majority of potential engine problems could be examined on the groudd. The pressure-fed system, however, could only be adequately tested during actual flight because of the large number of problems resulting from the interplay between propellant tanks and the engine. The pressure-fed engine, moreover, did not lend itself readily to "compartmentalization" for the purpose of telemetry checks to test performance. It was almost too simple; if something went wrong it was not always possible to determine exactly where the failure had occurred.

secured by inserting a diaphram--rubber balloon-- plug in the engine nozzle to maintain some pressure in the thrust chamber to assure ignition in a vacuum. Ignition would blow the plug out of the nozzle, and it would therefore be of no value for dual burn restart.)

After a number of conferences the Air Force agreed to the use of the Bell pump-fed, gimballed, rocket engine[43] for Agena, and this decision proved most fortunate with respect to the later requirement to combine Agena with the Thor booster. Propellants used with this engine were JP-4 and IRFNA (inhibited red fuming nitric acid) the first Agena A flight only. All subsequent Agena models have used the hypergolic combination of UDMH (unsymetrical dimethylhydrazine) fuel and IRFNA oxidizer.

Concurrent with the selection of the Bell rocket engine for the Agena, the "dual burn" satellite vehicle ascent technique was conceived by a young Lockheed engineer. In contrast to single burn where a satellite separates from the booster and coast to apogee before its engine is fired, in dual burn the satellite stage ignites right after separation and burns just long enough to provide a begin-coast speed sufficient for the long, shallow climb required for high efficiency. At apogee the satellite stage rocket is re-started to provide orbit injection. The greater begin-coast speed afforded by dual burn reduces the total amount of propellants required in the satellite stage and this can be replaced by increased payload. With the total cost of placing payloads in orbit at around $1,000 per pound in the early 1960's, the value of dual burn typically amounted to more than $1,000,000 per launching.

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[43] The Bell engine is gimballed in the yaw and pitch plane. Roll control is supplied by attitude gas jets during powered ascent.

This innovation was first proposed for use in combination with the Atlas A booster to compensate for its limited payload lifting capability and to provide for an earlier launch rather than waiting for the uprated Atlas C and D vehicles. The suggestion to attempt to use the Atlas A for early Agena flights was rejected by the Air Force, and the dual burn concept was dropped and not seriously reconsidered until direction to use the smaller Thor IRBM in 1958 made the approach highly attractive. A decision was made in late 1958 to delete engine closure in the first Agena A flight in order to demonstrate the feasibility of restarting a pump-fed engine in a vacuum without artificial pressure created by closure. The first Agena A pump-fed engine ignited properly in a hard vacuum, and the Agena B satellite subsequently incorporated a modified 16,000 lb. thrust Bell (8096) dual burn rocket engine which increased the total burn time to 240 seconds and provided a higher specific impulse through changes in injector design and a higher expansion ratio.

Auxiliary Power. The primary difficulties in providing required electrical power for the Agena satellite missions involved selection and development of lightweight power sources, and power inverter and regulator equipment. The power sources investigated during the Agena design study competition were batteries, open and closed cycle chemical power plants, solar cells, nuclear reactors, and radioisotope power plants. Battery units were selected for the early short duration flights; the simplicity of a battery-operated power supply was attractive for early use since the state-of-the-art permitted rapid adaptation, and they could also be employed as storage (or secondary batteries) for solar power units at a later date.

The silver-zinc oxide battery was in existance in 1957, and was chosen for early flights. Engineering accomplihhments in this area consisted of developing a pressure sealed silver zinc battery, increasing battery capacity, and developing a battery voltage regulator system that allowed conversion of battery power to well regulated DC at a high efficiency. Modified silver-zinc batteries are still flown on Agena satellites today,

Contemporary 400-cycle rotary inverters were considered for use on the Agena A because of the poor transistor quality found in solid state inverters. The rotary inverters, however, were heavy and of very low efficiency; taking no power output at all from the system a rotary inverter would still use about 22 amps, and would have limited life-on-orbit to a few passes at best. As a consequence efforts wererdevoted to design improvements in transistor quality innsolid state inverters, and these were subsequently flown. The Lockheed bridge-type 2KC inverter is one example of a design necessitated by the lack of high quality transistors.

The major downstream satellite power systems planned in 1956-1957 was the SNAP 1 and SNAP 2. This was a nuclear drive turbine electric plant, and also accounted for the selection of 2000 cycles because future SNAP systems were to operate at 2 KC alternating current. Initial power system development was therefore placed in line with development of nuclear power systems to come about later.[44] A solar power supply was planned to fill the intermediate step between chemical battery systems and a final nuclear system. In 1957, solar cells were in a position similar to that of transistors, and the combination of low efficiency and

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[44]The first experimental SNAP nuclear auxiliary power system was launched aboard an Agena in the SNAPSHOT program in 1964, and operated satisfactorily for over one month.

high power demand by the vehicle made early use of the solar cells infeasible. between 1957-1959 work on improvement in solar cells was conducted with subcontractors, and the first Agena using solar cells fixed to extendable solar arrays and storage batteries was launched in 1960. Since that time solar array designs have been further improved and presently can be employed in fixed positions or coupled with mechanisms to permit array rotation and sun tracking.

Guidance and Control. An accurate and reliable satellite guidance and control system was a prime requisite for intensified development during construction of the Agena. Experience with liquid propulsion systems and airframe manufacture existed prior to initiation of Agena development; however, by comparison, relatively little was known concerning the most efficient methods for guidance and control of large ballistic rockets and satellite vehicles during ascent, coast, and orbit injection phases, or of the attitude control of a vehicle on orbit. During the design study period Lockheed examined the whole spectrum of known guidance systems. These included radio guidance, inertial guidance, external reference guidance systems such as celestial navigation devices, and radar from the booster. Infrared guidance systems which observed the booster, observed stars, and observed the earth were all considered and rejected at one time or another during the design study. Infrared horizon sensors, which were under study and development in 1956, also were rejected for use in the Agena guidance and attitude control system as they did not appear as promising as they later proved to be.

The ascent guidance system proposed for the Agena satellite was very close to the system that was ultimately employed. It was an open loop guidance system using autopilot gyros in the booster (which was a radical idea at that time) with provision for orbit correction capability in the Agena. Operation would consist of programming the booster autopilot, radar tracking of the booster-Agena combination, computation of the time of initiation of Agena burn and velocity to be gained by Agena, and the command of these quantities into the Agena by ground radio link. Guidance elements in the Agena included three gimballed gyros, a single axial accelerometer, and an integrator. The "interim guidance system" that was finally developed and flown on all early Agenas was the same with the exception that a horizon sensor was substituted in place of gimballing the gyros to determine vehicle attitude. Flight path guidance and attitude control was maintained during Agena powered ascent by means of the Bell rocket engine, which was gimballed in the yaw and pitch plane, with roll control provided by cold-gas jets.

Shortly before award of the WS 117L contract to Lockheed, the Air Force directed that a closed loop three-axis all-inertial guidance system would be developed for the Atlas-Agena, and a contract for this effort was awarded to MIT in November 1956. The sophisticated all-inertial guidance system planned for the Agena was to employ gyro-stabilized accelerometers to perform complete trajectory control independent of any ground guidance, and was to achieve an orbital eccentricity of 0.003 whereas the proposed interim guidance system was expected to realize 0.001. Since control command would pass directly from the orbit stage Agena to the booster, the Agena was not independent of the booster.

Final development of an all-inertial guidance system for the Agena was prevented by a variety of economic and technical problems: (1) they were extremely heavy for satellite application and could not be used in combination with the Thor booster, (2) they were still in the R&D phase, (3) they would be very expensive, and (4) government priorities would not allow a sufficient number to be developed, produced, and released in time for the satellite test program. The Air Force authorized development of the interim guidance system in late 1957 in order to allow time to refine inertial guidance systems to overcome these problems, The interim system proved to be so accurate (with several years it was refined to the point where e-0.003) and reliable that it became a permanent feature on the Agena.

The requirement for three-axis orbit attitude control for Agena arose through the particular mission requirements that demanded a high degree of vehicle orientation and stabilization, During the design study,competition Lockheed investigated attitude control systems that had been devised under contract to RAND in the early 1950's, and proposed a refined gravity gradient control system for the Agena that had first been suggested by MIT. Attitude stabilization by gravity gradient involves using the vehicle mass distribution to attain an inherent stability relative to the earth's gravity field which, in a nose up or down position with respect to the earth, will tend to correct or right the vehicle from disturbing motions. This proposition is somewhat analogous to a water buoy which will right itself through its own weight distribution (heavy at one end). In a space satellite this correction to disturbing influence, because of a completely different environmental situation, is vastly more comples. A gravity gradient system without added control damping takes an extended period of time for attitude correction to be accomplished. Further, without added damping, the distrubing motions (torques) can reach a point where a dumbbell configuration will not be able to chedk it.

Inertia wheels were proposed for the Agena gravity gradient system to transfer the angular momentum of the vehicle to the wheels, with provision for applying additional damping and control torques from an external source (at first proposed as the exhaust gas from a chemical auxiliary power unit) to compensate for any excessive oscillations that might saturate the system. Eventual development of proportional control gas jets operating on nitrogen-freon supplied this latter requirement, horizon sensors coupled with three strap-down gyros comprised the attitude reference unit, and control moment gyros were employed as the inertia wheels.

For missions in which the Agena operates in a horizontal position with respect to the earth, as in the case of the early Discoverer program flights, attitude control is provided by the three gyro inertial reference package (IRP), horizon sensors, and proportional gas jets. The IRP contains two HIG (hermatic integrating gyro) units to sense pitch and yaw, and one MIG (miniature integrating gyro) unit to sense roll. The pitch and roll gyros are torqued by signals from the horizon sensors, and the proportional gas jets are actuated by signals from the IRP to correct any disturbing Motions.[45]

Recovery. During late 1957 the RAND Corporation investigated the feasibility of recovering research capsules ejected from earth satellites on orbit. Mr. Amron Katz, who was in charge of this work, concluded that contemporary science and technology would permit attainment of this goal,

[45]The length of time during which a specific gas jet or set of gas jets is fired is proportional to the magnitude of the disturbing torque, sufficient to stop the momentum without overcorrecting or undercorrecting.

and recommended development of a space recovery system. After evaluating the RAND report in early 1958, the Air Force authorized Lockheed to design, build and demonstrate a space recovery system on the Agena satellite.

The major technical problems presented by this new requirement were development of (1) a reentry body that would survive the slow steady heat pulse generated by atmospheric friction during a flat reentry trajectory, and (2) methods for recovering the capsule on the earth's surface. Consideration was first given to employing a spherical reentry capsule already developed by the General Electric Corporation for a ballistic missile program. The sphere was covered with ablative material and operated in a free fall on a ballistic trajectory. While it was found that the sphere could be further insulated to protect it from prolonged heating in a flattened reentry trajectory from orbit, the descent of the uncontrolled sphere could not be predicted accurately. Application of the spherical capsule was rejected.

The recovery capsule finally designed, constructed, and first flown on Agena A and B satellites was a conical shaped reentry body that somewhat resembled a thimble, with an ablative shell at the forward end providing thermal insulation. The payload capsule was mounted in the nose of the Agena and spin rockets and a retro rocket were incorporated to afford controlled reentry, with a parachute added to slow final descent. A configuration of the early research capsule and reentry body is shown in Fig. 6 . Recovery of the research payload capsule was programmed to occur on the high seas in the Pacific Ocean in order to avoid any complications with commercial air traffic and national boundaries.

Recovery operations devised for retrieving the space capsule consisted of a two-phase technique that is a significant story in its own right. It

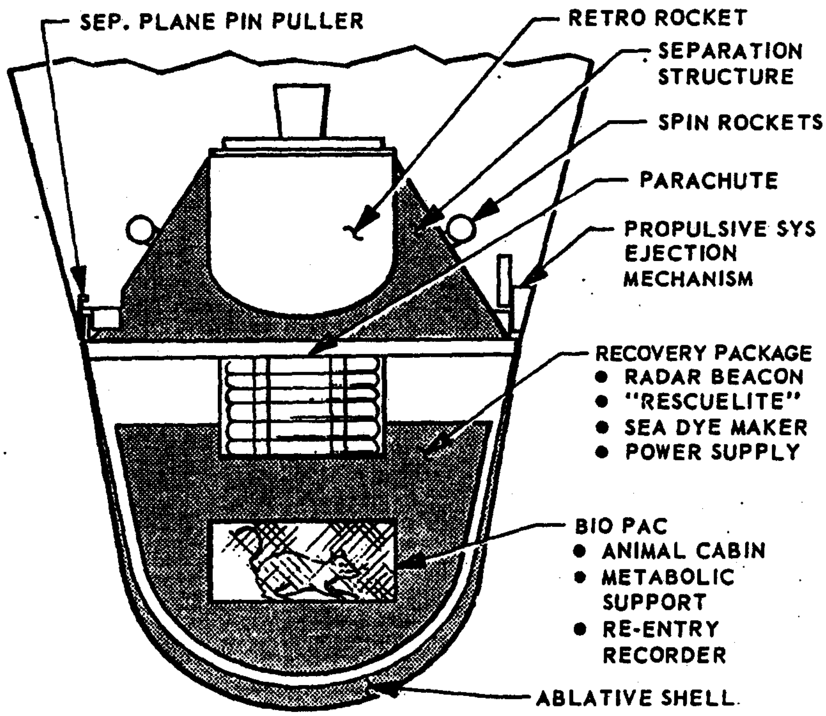

Fig 6. Agena Recovery Capsule-1960

will suffice here to note that an air and sea recovery takk force was created; large aircraft were modified with special equipment to permit snagging the capsule parachute during its decent where upon the capsule could be reeled into the aircraft. In the event air recovery was not accomplished the capsule impacted the water and would float until backup sea recovery was effected by ships, heliocopters and para=rescue teams.

Operation of the payload capsule is described in the following sequence of events for separation, reentry, and recovery. Initially the Agena and reentry capsule were placed on a polar orbit in a horizontal position with respect to the earth and, at a given command, the Agena performed a yaw maneuver turning 180 degrees so that it was positioned backwards to the line of flight. Upon receipt of a signal to eject the capsule, the Agena pitched down 60 degrees and the reentry body was released by a set of pin pullers and springs. Shortly after separation two solid propellant spin rockets fired and the capsule was spun to approximately 60 rpm at which time the retro rocket was ignited for about 10 seconds. Following retro rocket burning the capsule was despun to a spin rate of 7.5 rpm for bio-medical and aerodynamic considerations by firing two remaining solid spin rockets. At this point the thrust come and retro-rocket were ejected to increase aerodynamic stability during reentry and, after the capsule had descended to about 60,000 feet altitude, the aft thermal cover was hurled out of the capsule by a drouge gun drawing the parachute out after it. Upon parachute deployment the payload capsule separated from the ablative shell, the recovery system's radio beacon and flashing light were activated, and the beacon antenna was erected. This sequence of events appears in Fig. 7

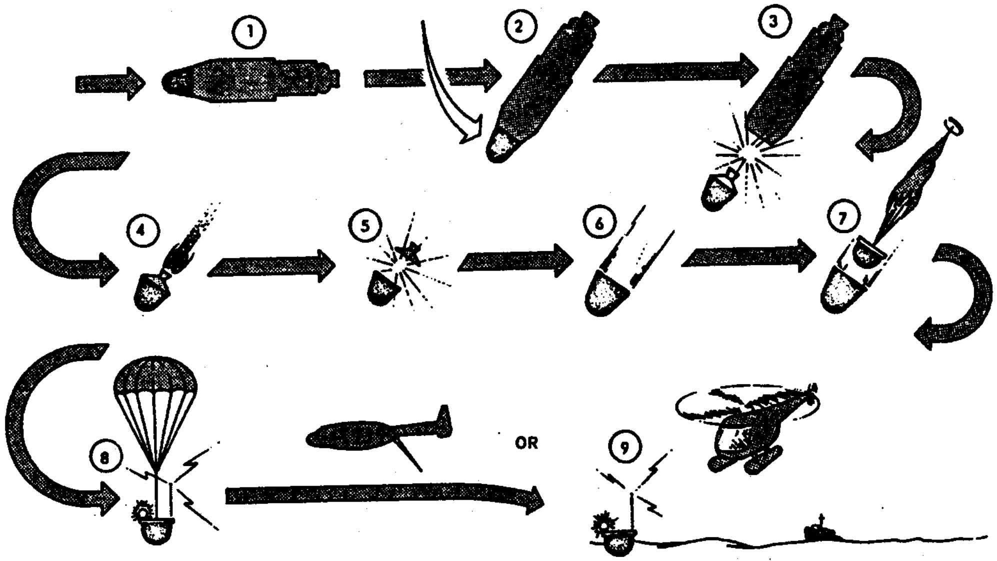

Fig 7. Reentry and Recovery Sequence of Events - 1960

The first payload ejection and recovery attempts made during 1959 and 1960 were unsuccessful, and the limited instrumentation providing telemetered diagnostic data did not pinpoint the exact cause of capsule malfunction during reentry. All that became known with certainty was that a malfunction was occuring during the spin-up and retro fire sequence of events. A special investigation of the characteristics exhibited by a payload that had ejected and gone into another orbit finally indicated what in fact was actually happening: the solid spin rockets were exploding on ignition (determined to be caused by aging of the solid-propellant). The four solid propellant spin rockets were removed and replaced by two opposing gas jets using compressed nitrogen-freon to provide capsule spin and de-spin torques. Successful demonstration of the research capsule orbital reentry and recovery techniques took place on August 10, 1960, when the first capsule employing new cold gas spin jets was ejected from orbit and recovered in the Pacific Ocean.

Recent Innovation

Throughout the engineering and operational development phase, Agena A and B satellites were constructed on a job-shop basis, that is, each vehicle (or group of vehicles) was tailored to meet the requirements of a specific using program. While the configuration of the spaceframe remained basically the same, the kind of wiring, location of various equipments, and the size and shape of equipment racks differed significantly. This built-in dissimilarity made transfer of Agena satellites from one program for use in another program impractical without major modifications. The cost of major modification, in turn, made transfer uneconomical.

In early 1959, Lockheed began studies, in conjunction with the Advanced Research Projects Agency (ARPA), to design a simplified Agena that could be employed in any satellite program with a minimum of rework; authorization to proceed with design and production of a standardized Agena was granted by ARPA. The new vehicle was to be an optimized, simplified, terminal stage attitude-stabilized satellite incorporating a Bell (Model 8096) rocket engine with a single restart, and capable of accommodating a wide range of payload applications.

The new satellite design was identified as the Mark I Lockheed Spacetruck, and plans initially were made to employ four of the new satellites in ARPA's Transit (navigation satellite) Program and two in their Courier Program (an early version of the military communications satellite).[46] Shortly after work on the Spacetruck vehicle commenced, however, the Department of Defense issued orders redirecting policy management for United States military space programs, and the Air Force replaced ARPA as technical director of the WS 117L Program. Spacetruck development initiated by ARPA subsequently evolved to become the uprated Lockheed Agena B satellite which continued to be built on a job-shop basis and did not adhere to the original production ideals. Once having been introduced, however, the concept of a standardized Agena satellite vehicle continued to be held in several circles.

In the spring of 1961 further design studies by Lockheed, in cooperation with Air Force personnel, yielded strong indication that a

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[46]Lockheed Secret Report LMSC/447999, Satellite Systems History, Vol. I, Section 2.8, "Other Programs," Part III, "Agena D Program," 1962, p. 2.8-3-2.

standardized configuration of the Agena B satellite could be formulated. After additional discussions and review, the Air Force authorized a formal three-month study to provide a recommended approach to standardization, and the criteria for such a design. The objective of this study program was to isolate those portions of the Agena B which were common to all programs and all the uncommon functions and components that were peculiar to specific using programs in order that a standard vehicle could be designed.

Upon conclusion of this study, in September 1961, Lockheed published an Agena B Standardization Study, LMSC/448564 (a thorough analysis of the common and uncommon functions and equipment for all programs employing the Agena B flight article), completed a preliminary mockup of the contemplated standardized vehicle, and submitted various cost, time, and engineering estimates to the Air Force. Results of this study showed a Standard Agena to be both feasible and economically desirable. Some of the prime characteristics of the new configuration, in contrast to the Agena B, were:

1. Removable, separate wire harnesses
2. Location of common equipment for easy installation and removal
3. Open-frame aft rack with provisions for "optional" equipment to be added
4. Four-track rather than three-track booster separation rail system
5. Placement of the helium tank pressurization sphere in front of the propellant tanks

Three fundamental categories of items necessary in the standardization activity also were introduced: (1) common basic items (items used in all or nearly all programs), (2) optional items (items used on two or more programs), and (3) program peculiar items (items used on one program).

One of the most important elements in the Standard Agena concept was the increase in reliability which would almost automatically result from the repetitive aspects of manufacturing and operating a standarized production item with frozen component specifications and the elimination of recycling. A detailed analysis of prior Agena trouble areas and improper performance made during the standardization study indicated that approximately 50 percent of all flight failures resulted from difficulties occurring in the areas of production (difficult installation, complex systems, additional recycle engineering modification after assembly), and in maintenance and accessibility (insufficient engineering control in vehicle wiring, complicated plumbing and connections, and contamination of fluid and pneumatic systems). It was determined that a Standard Agena would largely eliminate these problems as well as provide improvements in environmental control, and reduce random component failures and flight operational errors.

The new satellite vehicle was designated "Agena D,"[47] and on August 25, 1961, Letter Contract AF 04(695)-21 was awarded to Lockheed to develop and manufacture the first twelve flight vehicles, with a first launch scheduled for January 1963. A few months later, on October 17, 1961, Dr. Joseph Charyk, Under-Secretary of the Air Force, appointed a committee chaired by Mr. Kelley Johnson of Lockheed, to investigate ways

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[47] A Lockheed proposal to develop an Agena "C" made in early 1961, which involved major changes in propellants, tank design, and a modified Bell rocket engine, was turned down by the Air Force. See Lockheed Secret Report LMSC/448266, <u>Proposal: Design and Development of Agena C</u>, 21 June 1961.

to further improve vehicle reliability and advance development and production schedules. The committee report was submitted on October 25, and recommended acceleration of the program and outlined the requirements necessary to meet an earlier launch date in mid-1962. The proposed accelerated program was given an immediate go-ahead by the Air Force on November 7, 1961.

The principal objectives of the Agena D Program Plan (December 12, 1961) were the provision of Agena D vehicles at the earliest possible time and a fixed price source of procurement for Agena vehicles at Lockheed. To accomplish these objectives a completely new projectized Lockheed organization was created and a detailed set of administrative procedures was established to cover all phases of the program. A hand-picked team, including the initial design organization, was assembled to carry out this assignment, and a segregated "skunkworks" was established in a separate building to contain the program management, design, and much of the production activity. Operating on a concurrency basis throughout design, manufacturing and test, the first Agena D was sold to the Air Force on April 16, 1962, and program peculiar equipment was installed complete on April 27. Agena D No. 1 was launched on June 27, 1962, seven months after go-ahead was given the accelerated program. In this first launch the Agena D vehicle performed satisfactorily and all flight objectives were achieved. The Agena D presently continues to be produced and furnished as a standard item to the using program where program peculiar equipments are added.

During the early phases of development work under contract, additional improvements were established and incorporated in the basic

Agena D including:

1. Primacord separation from the booster, replacing explosive bolts
2. Standardized payload interface console
3. Orifice pressurization helium system
4. Rapid-dump tank venting
5. Major equipment items collected into four convenient "modules" (guidance, power, telemetry, and beacon)
6. Interchangeable joints at both ends of the propellant tanks
7. An Atlas booster adapter to consist of a Thor adapter plus an extension

Since 1962 the Agena D has been further modified by the substitution of beryllium metal for door panels and portions of the vehicle skin in place of the mag-thorium which was previously used. This change, made possible by improved techniques for working beryllium, has resulted in a lower inert weight for the Agena and a corresponding increase in payload lifting capability. A new optional multi-start Bell pump-fed rocket engine (Model 8247) also can be substituted for the dual-burn (Model 8096) engine, and small-thrust vernier rocket engines are available for missions that require limited propulsion power in small increments on orbit. This latter Secondary Propulsion System (SPS) is composed of two modules designed to fit on each side of the Agena D aft rack, and is a pressure-fed multi-start system using liquid hypergolic propellants in self-contained tanks. The SPS provides two levels of thrust: 16 lbs. and 200 lbs. from separate rockets. The vehicle configuration of Agena D appears in Figure 8, below.

In conjunction with development of the basic standard Agena D, various other innovations have been made in engineering techniques and in vehicle equipments to improve overall Agena reliability and capabilities

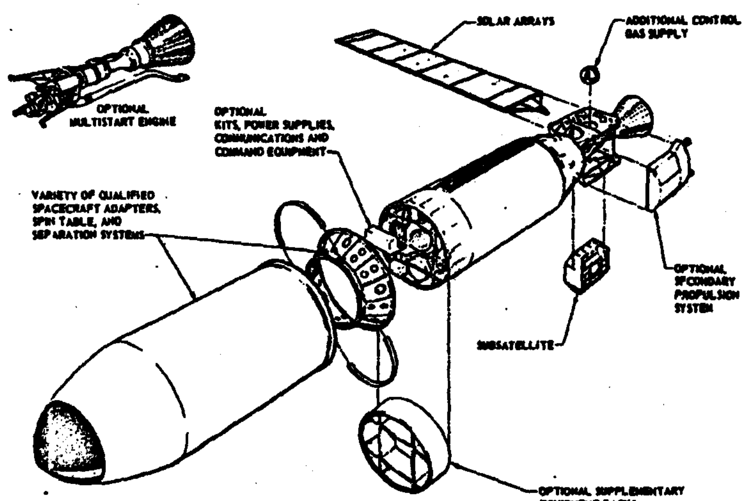

Fig 8, Agena D satellite 1962 –

in ascent and orbital operations during the 1960's. Chief among these innovations are the development of a "piggyback" subsatellite that can be employed in a separate mission from that of the main Agena mission, a technique to conserve Agena electrical power and control gas on orbit, and new equipments to increase electrical power and the accuracy of Agena guidance and attitude control.

In late 1962 a Lockheed proposal to design, develop and launch a subsatellite spacecraft from Agena satellites to perform independent research missions was approved by the Air Force. The space vehicle that resulted from this work is a small, compact, subsatellite which mounts on the Agena aft equipment rack during ascent and is ejected on orbit. This unit, which appears in Figure 8, is spin stabilized, solar-cell powered, and contains a solid-propellant rocket for injection into a separate secondary orbit. Depending on the Agena primary mission orbit profile, and upon the engine selected for the subsatellite, it is capable of attaining a variety of orbits ranging from highly elliptical to low, nearly circular orbits.[48] The first subsatellite was launched from an Agena in April 1963, and since that time they have been employed as a scientific probes on various Air Force satellite programs.

A deactivate-reactivate technique for conserving Agena electrical power and attitude control gas for extended-duration missions was developed at Lockheed in 1962. The deactivate sequence is controlled by a preset timer which is started by real-time ground command, and provides for the shut-down of certain vehicle equipments. In the deactivated mode the Agena

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[48]Lockheed report LMSC/A605327 (Official Use Only), Agena Application to Space Missions, September 26, 1964, p. 26.

is spin stabilized in the pitch plane (tumbled end over end at a 3 degree/second pitch rate) to provide an equalized thermal gradient over the vehicle with a minimum power consumption for heating low-temperature-sensitive equipment. Some time later vehicle reactivation is accomplished by reintroducing electrical power to the guidance and control system which is programmed to remove the 3 degree/second pitch rate. Within a brief period the horizon sensors view the earth and reorient the vehicle properly. The deactivate-reactivate sequence was successfully demonstrated on an Agena D satellite in April 1963; flight experience with this technique has proven that no search mode is necessary for re-establishing earth reference.[49]

Agena flight performance has been improved by increasing the efficiency of the electrical power plants and the accuracy of the guidance and attitude control system. Improvements in primary batteries has increased the power output from 55 watt hours per pound in 1959 to 100 watt hours per pound in 1966 (smaller high discharge-rate batteries are used for ascent-only missions) and the contemplated introduction of gaseous storage and cryogenic auxiliary power fuel cells is expected to push this figure to 500 watt hours per pound in the near future. The Agena guidance and control system has been modified since 1959 by incorporating (1) two twin-head horizon sensors with the three-axis body-mounted gyro package in place of one single-head horizon sensor which has improved ascent inclination accuracy through more rapid acquisisiton of the earth, (2) Bell Telephone Laboratory (BTL) radio guidance on the Thor booster in 1960 which improved the period, flight path angle and inclination accuracy, (3) a

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[49] *Ibid.*, p. 42.

digital velocity meter (which terminates main engine thrust after the vehicle has increased its velocity by a predetermined increment) on the Agena in 1962 which decreased the period and flight path angle dispersions, and (4) BTL radio guidance on the Agena in 1963 increased the closed loop steering of the ascent vehicles, further decreasing all injection dispersions.

The Agena attitude control system has been radically improved over that of the original Agena A, and is presently capable of a variety of dead bands and programmed maneuvers. The rate of change in vehicle attitude (limit cycle rate) and expenditure of control gas has been reduced by an order of magnitude[50] by replacing the original rate gyro with passive rate circuits and proportional control gas jets in 1961, by improving the roll rate gyro (by replacing one HIG gyro with a MIG gyro) and by introducing the Barnes Mod IIA horizon sensors in 1963. Recent improvements in limit cycle rates have accrued from optimizing the system gains and dead bands. In addition, a backup attitude stabilization system was developed at Lockheed in 1961 to provide a redundant capability in the event of failure of the primary Agena attitude control system. The backup system is a self-contained command, sensing, and gas-jet control system which aligns the Agena with the local magnetic-flux field (as established by magnetometers) to ensure correct vehicle attitude. This system was first flown in May 1962, and can be used either as an automatically operating device or it can be activated by ground-command should

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[50] An original capability of 0.8 degree attitude null offset and limit cycle rate of 0.05 degree/second has been improved to the present level of 0.3 degree attitude null offset and limit cycle rate of 0.02 degree/second.

it become apparent that the regular attitude control program has become inoperative.[51]

Original development of the Agena to meet the requirements of United States military space programs in the late 1950's and subsequent changes and innovations have resulted in a spacecraft that can be employed as an upper stage, an intermediate stage or as a satellite vehicle. It can be equipped with options such as a multi-start primary propulsion system, extendable solar arrays, a secondary propulsion system, and sub-satellites. In addition to an active orbital three-axis attitude-stabilized mode, the Agena offers options of gravity-gradient stabilization with control moment gyro damping, and spin stabilization. It has performed as an upper stage booster in diverse programs such as the Mariner Mars and Venus probes, Nimbus weather satellites, and Ranger lunar impact probes, and as a satellite in the Gemini rendezvous-docking program and in a number of military space programs. Since its first launch in 1959, the Agena has been flown more than any other space vehicle, and remains today the only American satellite with a demonstrated capability of ejecting payloads from orbit for recovery on earth.

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[51] Agena Application to Space Missions, op. cit., p. 44.

CONCLUSION

Realization of the contemporary operational "off-the-self" Agena vehicle that can be readily adapted to meet ascent and orbit requirements for a variety of space missions was made possible by the contributions of numerous individuals over a period of some twenty years. As we have seen no single person was responsible for the concept of the Agena or for a majority of innovations in the various technical disciplines that made it possible. During this time intermittant reluctance to accept technological innovation was encountered in the research and development process, first for the satellite itself, and later for proposed alterations in vehicle functions and design. For the most part these instances of resistance to change, both by government agencies and industry, were occasioned by reasoned differences of opinion over technological and economic practicality. Some resistance to new developments evidenced by those in a decision making capacity also resulted from what Elting E. Morison has termed "limited identifications:"[52] that quality of outlook generated by close association with a product or system which prevents those involved with it from grasping either its defects or potential. For example, there was strong reservations in several quarters at Lockheed against accepting the proposal to discontinue job-shop construction of Agena B vehicles and proceed with development of the standard Agena D in 1961. The argument ran that since experience in tailor-making space-

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[52] Elting E. Morison, "A Case Study of Innovation," originally delivered as a lecture at the California Institute of Technology in March, 1950.

craft for separate space programs had proven technically successful and economically profitable it would be unwise to radically alter the system by introducing a common production spacecraft, and that any new version of the Agena should be produced on a job-shop basis. This reasoning equated prior success to one separate process, and the economic and technological advantages that could result from standardized construction and checkout of space vehicles did not receive primary consideration. The tendency toward limited identification is not confined to a particular moment in history or to a specific group, it has been frequently encountered in indsutry,[53] in government services[54] and, indeed, in American society in general. Even as dynamic a society as our own, as we like to represent it, resisted adoption of the motor car, the airplane, and more recently, but perhaps to a lesser extent, the long-range rocket and satellite. Today there is evidence that social discontent with sonic booms that will accompany projected high-speed performance of the Supersonic Transport (SST) will create national controversy in this country when

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[53]Resistance to change in a company with long established practices is often sufficiently critical to cause the loss of the company's economic position or, in extreme cases, the failure of the company. For a case study in the plate glass industry, see Richard A. Smith "At Saint-Gobain, The First 300 Years Were the Easiest," Fortune, October 1965, pp. 148ff.

[54]See Morison, loc. cit; also, for example, at a meeting in Washington D. C., in May 1940, Dr. Robert Goddard presented the findings of his research in rocketry to members of the Navy's Bureau of Aeronautics, the Army's Ordinance Department, and the Army Air Corps in an attempt to interest these services in developing long-range ballistic rockets for military use. "At the end of the conference the Army representatives said they still felt that 'the next war will be won with the trench mortar.' The Air Corps and Navy people saw no possibilities in the rocket as a missile weapon. . ." G. Edward Pendry, "The Man Who Ushered in the Space Age," contained in Robert H. Goddard, Rocket Development, Diary of the Space Age Pioneer, E. C. Goddard and G. E. Pendry, eds., (New York: Prentice-Hall, Inc., 1961), p, xix.

developmental flight test begin over land areas.

The impact of technological innovation is not confined to the community where first it originates. As no single nation posses a monopoly on scientific know-how, (and if one subcribes to the message of Marshall McLuhan), new techniques and innovation spread world-wide, changing the patterns of social, economic, political and even religious organization and behavior by the very fact of their existence.[55] As extension of man, aircraft and today spacecraft literally collapse time and distance; where "by speed-up the airplane rolls the highway into itself . . . and becomes a self-cpntained transportation system,"[56] orbiting spacecraft, in turn, carry this proposition to the point where the circumference of the earth shrinks to commute times and day and night comes and goes nearly on the hour. The phenomenal rapidity of discovery and applied refinement in aerospace technology--from 1900 when only very limited technical information concerning rocketry and astronautics was available, to the present where governments are forced to cope with a superabundance of this technical data--makes any speculation about the future affects of space exploration on the world community highly uncertain. Economic applications of

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[55]Prevailing attitudes of a community that are receptive to technological innovation, while not altering the ultimate impace over the long run, can appreciably influence the rate at which innovation is assimilated in organizational and behavioral patterns. Jewkes, Sawers and Stillerman have observed that "every community has to decide how best to maintain continuity and a reasonable measure of stability while leaving open channels for new ideas and room for change. It cannot afford to be tossed defenselessly by the demonic impulses of the innovator, yet it can ignore him or suppress him only at the risk of stagnation." John Jewkes, David Sawers, and Richard Stillerman, The Sources of Invention (London: MacMillan & Company Ltd., 1958), p.8.

[56]Marshall McLuhan, Understanding Media, the Extensions of Man (New York: MacGraw-Hill Book Company, 1964), p. 182.

earth orbiting vehicles, for example, portend new avenues for communication, weather prediction and control, locating mineral and animal resources, mapping, and predicting water flow amont numerous potentialities.

The Agena, which has been flown more often than any other space vehicle, will retain a prominent place in these space endeavors of the future. From its first conceptual origins in the Air Force-RAND feasibility and mission definition studies of the late 1940's and early 1950's, the Agena progressed through three vehicle configurations during the research and development period--within the first five years of the Space Age. It changed from a hand-built job-shop research and development space vehicle to a simplified, standard production item that, like a popular sports automobile, "can be designed by you" to meet a number of mission requirements by selecting the necessary optional equipments. To date, in over 200 flights, vehicle reliability in achieving predetermined flight objectives has increased from 47 percent for the early Agena A, to 90 percent for the standard Agena D. The evaluation of Agena configurations is shown in Table 1, below.

Dr. Edward Welsh, Executive Secretary of the National Aeronautics and Space Council, has offered what is perhaps the most concise summary of Agena capabilities and historic achievements druing a luncheon address on February 4, 1965, following presentation of an Agena to the Smithsonian Institution:

> As the presentation was being made,you were reminded--and they are worth repeating--of the Agena's 'firsts,' such as being the first satellite to achieve a circular orbit, first to make polar orbit, first to be controlled in three axes during flight, first with a pump-fed engine to provide a restart capability, and first to return a man-made object from orbit. . . More can be said about the Agena at the proper time and place and under the proper conditions. Needless to say, it is a versatile space star.

These achievements soon should be superceded by others made by new

VERSION	INITIAL CHANGE	SUBSEQUENT CHANGES	ANCILLARY DEVICES
AGENA A	BELL MODEL 8048 PUMP-FED ROCKET ENGINE	UDMH FUEL (MODEL 8048) SINGLE-HEAD IR HORIZON SENSOR	RECOVERY
AGENA B	DUAL BURN ROCKET ENGINE (MODEL 8081) 240 SEC DURATION DOUBLED PROPELLANT TANK VOLUME WITH INTEGRAL TANKS	DUAL BURN ROCKET ENGINE (MODEL 8096), HIGHER EXPANSION RATIO AND IMPROVED INJECTOR DESIGN, HIGHER I_{sp} FUEL-POWER HYDRAULICS TWIN-HEAD IR HORIZON SENSORS AND IMPROVED IRP WITH MIG GYRO VELOCITY METER PULSE GAS JETS	SOLAR ARRAY CONTROL MOMENT GYROS SECONDARY PROPULSION SYSTEM TYPE III FM/FM TELEMETRY
AGENA D SS-01A	INTERCHANGEABILITY MODULARIZATION ORIFICE PRESSURIZATION FOUR-TRACK SEPARATION RAILS INTEGRATED INSTRUMENTATION	RAPID PROPELLANT DUMP TYPE V FM/FM TELEMETRY PRIMACORD SEPARATION	BACKUP ATTITUDE CONTROL SYSTEM
SS-01B	ULLAGE CONTROL BY PROPELLANT TANK PASSIVE CONTAINMENT SUMP SCAVENGING BERYLLIUM DOORS/SKIN BTL RADIO GUIDANCE	TYPE 12 INVERTER BARNES MOD IIA HORIZON SENSORS	SUBSATELLITE DEACTIVATE/REACTIVATE
S-01C	MULTI-START ROCKET ENGINE (MODEL 8247) PROPELLANT ISOLATION VALVE		TYPE I PCM TELEMETRY

Table 1 Agena Configuration Changes

Agena configuration, for the demands of new space programs and the pace of developments in astronautics technology dictates change to embrace these requirements. Presently, design is underway preparatory to construction of a new version of the standard Agena that will permit lifting heavier payloads and increase vehcile lifetime on orbit. Assuming space exploration will contribute to continued change in the course of human affairs, we can reasonably expect that the Agena will continue to play a significant role in these developments.