DEPARTMENT OF THE ARMY
UNITED STATES ARMY GARRISON – REDSTONE
4488 MARTIN ROAD
REDSTONE ARSENAL, ALABAMA 35898-5000

REPLY TO
ATTENTION OF

May 27, 2010

Freedom of Information
Program Office

Mr. John Greenewald Jr.
[redacted]

Dear Mr. Greenewald Jr.:

This is in response to your Freedom of Information Act (FOIA) request received April 9, 2010 for Accession Numbers: ADB217494 and AD0395808 as stated in your request.

Your request has been reviewed by the US Army Aviation and Missile Command's Acquisition Center and much coordination with Scott Air Force Base, a copy of the requested documents are attached.

Pursuant to the Freedom of Information Act, 5 U.S.C. 552, there were no costs associated with processing your request.

If you have any questions concerning this response, please call the undersigned at 256-876-6360, and reference case number **FOIA-10-0265.**

Sincerely,

//s//

Charmaine Howell
Freedom of Information/Privacy Act
Program Specialist

Enclosure

Individual Lift Device.

BELL AEROSYSTEMS CO BUFFALO NY

15 OCT 1967

UNCLASSIFIED / LIMITED

UNCLASSIFIED / LIMITED

PH 30,096

INDIVIDUAL LIFT DEVICE (u)

CONTRACT NO. DA23-204-AMC-03712(T)

"DTIC USERS ONLY"

REPORT NO. 21

OCTOBER 15, 1967

Report No. 2203-933021

Declassify: OADR
Authority: DoD 5200.1-R, Para 4-600b

BELL AEROSYSTEMS - A textron COMPANY

Rec'd 10-18-67 Bell via CDC

DAY-SALMON

UNCLASSIFIED

BELL AEROSYSTEMS COMPANY

CDC - M

[redacted]

INDIVIDUAL LIFT DEVICE

REPORT NUMBER 21

October 15, 1967

ARPA Order Number	764
Program Code Number	6G20(23)
Name of Contractor	Bell Aerosystems Co.
Date of Contract	30 December 1965

Contract Number	DA 23-204-AMC-03712(T)
Contract Expiration Date	1 March 1968
Project Title	Individual Lift Device
Project Manager	Robert J. May
Technical Director	Robert F. Speth

NXT

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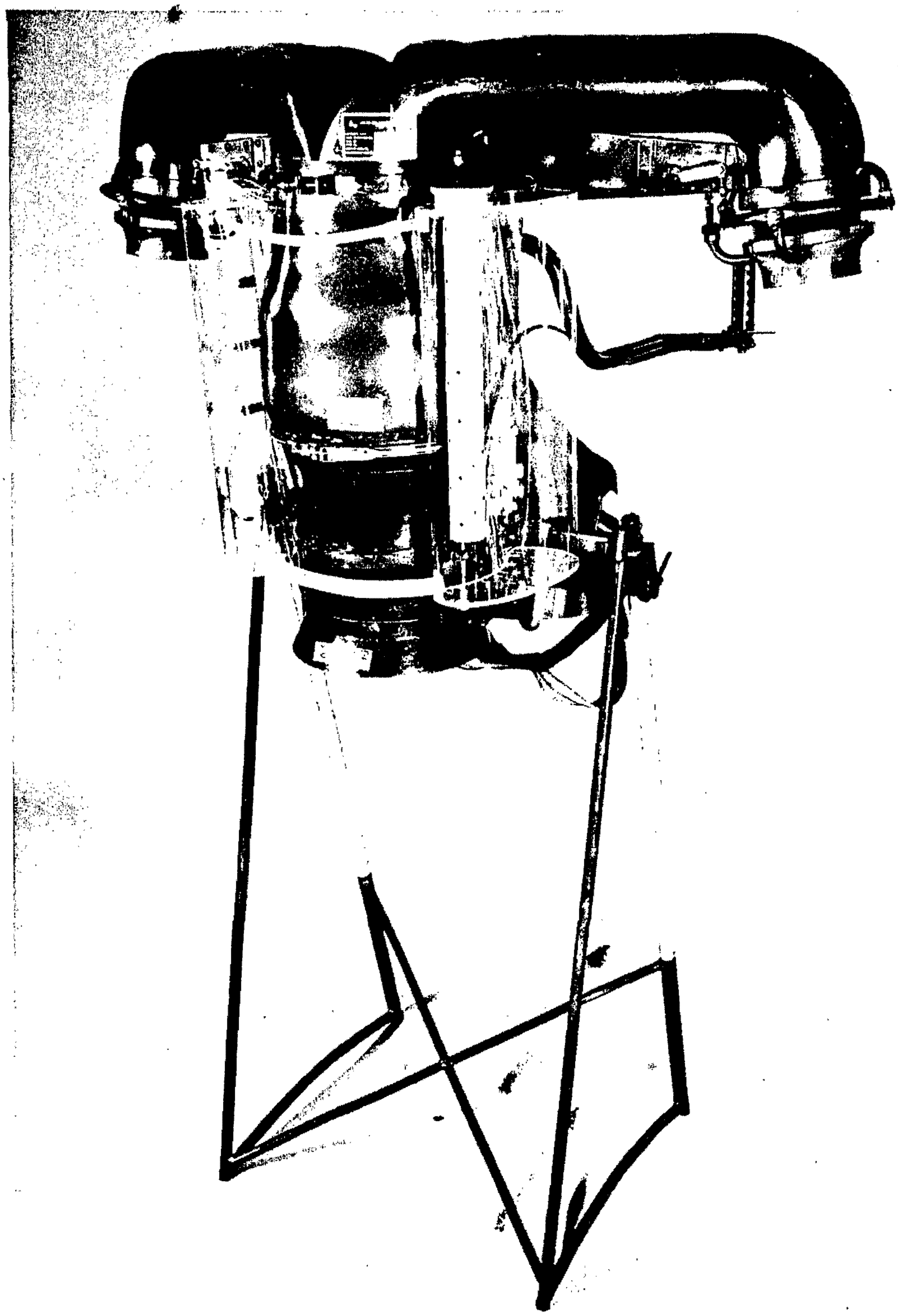


Jet Flying Belt

INDIVIDUAL LIFT DEVICE PHASE II

SUMMARY

The Phase I design portion of the program was completed in approximately November 1966 and resulted in the Individual Lift Device configuration which is shown in the frontispiece (Jet Belt Mockup). The engine is mounted inverted in a vertical attitude and exhaust gases are ducted through a rigid bifurcated duct system to nozzles located at the extremeties and pointing downward. Nozzles are suspended from the duct by a bellows which permits deflection fore and aft and to the sides for control. Control inputs and engine throttling are achieved as in the rocket belt. Wrap around fuel tanks are used and are unpressurized. Empty weight is 99 lbs. including the engine. With a 180 lb. man, 25 lbs. payload, and 44 lbs. of fuel and oil, take off gross weight is 348 lbs.

The engine which is 1 foot in diameter and 2 feet in length is a twin spool, bypass turbo jet engine with a minimum rated thrust of 425 lbs. The two spools are counter rotating to minimize gyroscopic forces during maneuvers. Design specific fuel consumption is 0.8 lbs. fuel/lb. thrust/hour. Airflow is approximately 11.65 lbs./second.

Calculated performance indicates the jet belt can be flown to speeds over 100 miles per hour and to ranges of 10 miles.

The program is now well into Phase II which entails fabrication, development testing and delivery of flight qualified hardware. This is followed by Phase III, flight demonstration tests.

END.

During the past month, the first Jet Belt was sent to Williams Research for engine mating and the first complete system was assembled. A few minor interferences were noted and the belt was returned to Bell for rework. Consistent with new detailed program planning, it will be sent to Williams Research during October for test cell installation. The second bifurcated duct assembly is well along and will be mated to the rest of the Jet Belt during this month.

Further engine testing was accomplished during the reporting month for a new total of over 7 hours of running time achieved, which included acquisition of many data points. A speed of 95.5% of rated (52,500 RPM) RPM was reached. A bearing heating problem was encountered at this high speed which necessitated rework of a portion of the engine internal lubrication system. Engine thrust level, which was tracking the design data extremely well until this high RPM point fell off slightly. The thrust dropoff is attributed to excessive radial compressor clearance and appropriate modifications are being incorporated. The engine is expected to be reassembled and running by 10 October with the previously stated modifications incorporated. Major mechanical problems have been non existent to date. Data and testing to date indicate the engine rated thrust and specific fuel consumption appear achievable in the present configuration.

Delays encountered in the 4th stage stator fabrication have further delayed assembly of the second engine (endurance) which is currently pacing the program. It is expected to be completed and running by Monday, 9 October which is approximately two months behind the previous plan. Contrary to the estimate in last month's report, this delay has now resulted in a five week extension of the overall program and has an attendant cost increase. Detail planning has been accomplished and is reflected in the current schedule in the Program Plan section of this report.

A Proposal letter is being prepared and will be submitted in early October reflecting the detail plans for completing the program, and new estimated costs at completion. It is anticipated that this letter will be the basis for negotiation of a contract amendment to formally define the revised scope of work program pursued since March.

INTRODUCTION

In April 1964, Bell Aerosystems Company and Williams Research Corporation submitted a joint unsolicited proposal to the U. S. Army Mobility Command and subsequently to ARPA for design, fabrication and test of an Individual Lift Device known as the Jet Flying Belt. As a result of this proposal a prime contract was awarded to Bell Aerosystems Company on 30 December 1965. The program is being funded by ARPA and administered and directed by the U. S. Army AVCOM in St. Louis. Williams Research Corporation was subsequently selected by Bell as a major subcontractor to develop the power plant.

The Jet Flying Belt utilizes essentially the same general configuration and control concept successfully proven on the Bell Rocket Belt which has accumulated over 3000 flights to date. The Jet Belt is powered by the WR-19 bypass fan engine being developed by Williams Research for this application. This propulsion system significantly improves endurance, range and utility over the rocket powered system.

The purpose of the Individual Lift Device or Jet Flying Belt is to provide a substantial improvement in individual soldier mobility for a variety of select mission applications such as (1) Observation (2) Reconnaissance (3) Forward observation and liaison (4) Overcoming natural and man made obstacles (5) Clandestine operations and (6) Delivery of personnel and parts for in-place maintenance.

The basic objective of the present contract is to develop a flight demonstration model to demonstrate feasibility of the system, and ranges up to 10 miles and a speed of 60 mph. One flying belt, a spare engine, residual hardware and data are deliverable items, under the contract.

Bell, as Prime Contractor, is responsible for overall system management, system integration, design, fabrication and flight test. Williams, as a subcontractor, will design, fabricate and test the engine. Olin Mathieson has been selected to develop a solid propellant cartridge for use in the Jet Belt self contained start system.

INDIVIDUAL LIFT DEVICE PHASE II

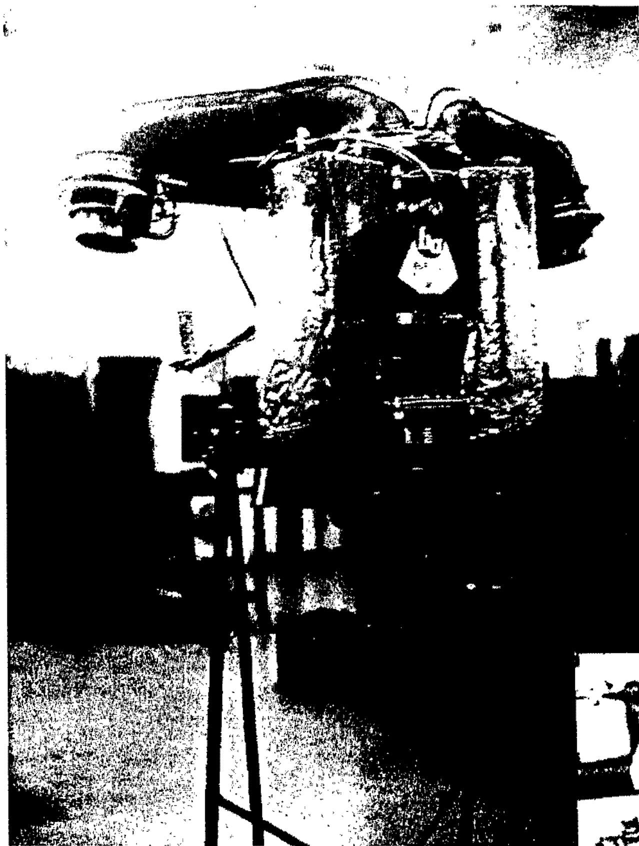
GENERAL

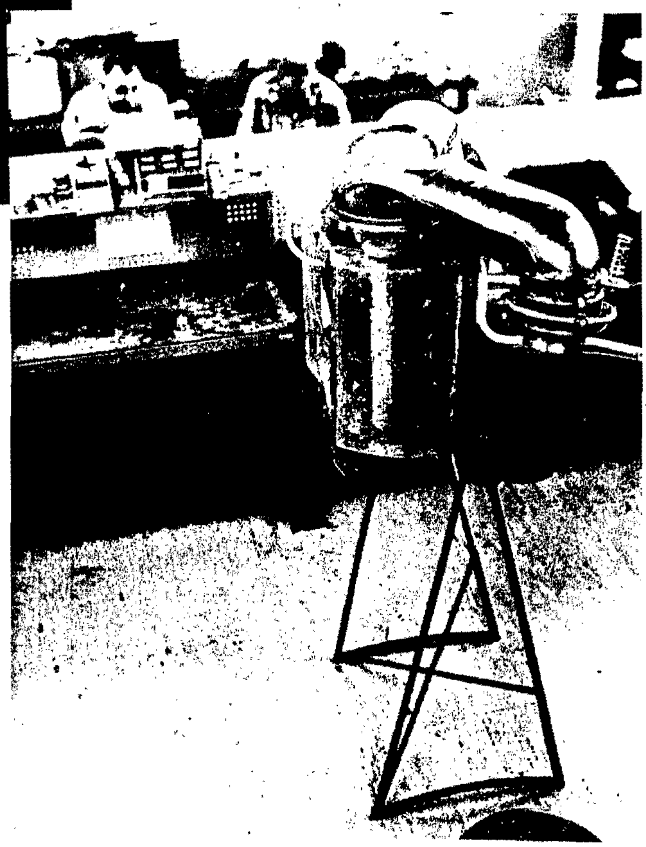
During the past month Williams Research has been engaged chiefly in making modifications to the performance engine and build-up of the endurance engine. Modifications have been concerned with improved burner configuration, reducing the clearance gap on the radial flow compressor, and the oil supply system to the fourth and fifth bearing which have been overheating at high speeds. At Bell, the first Individual Device was completed and the second bifurcated duct and nozzle system was begun. A set of six proposals for follow-on work after the present contract, were completed and submitted.

JET BELT HARDWARE

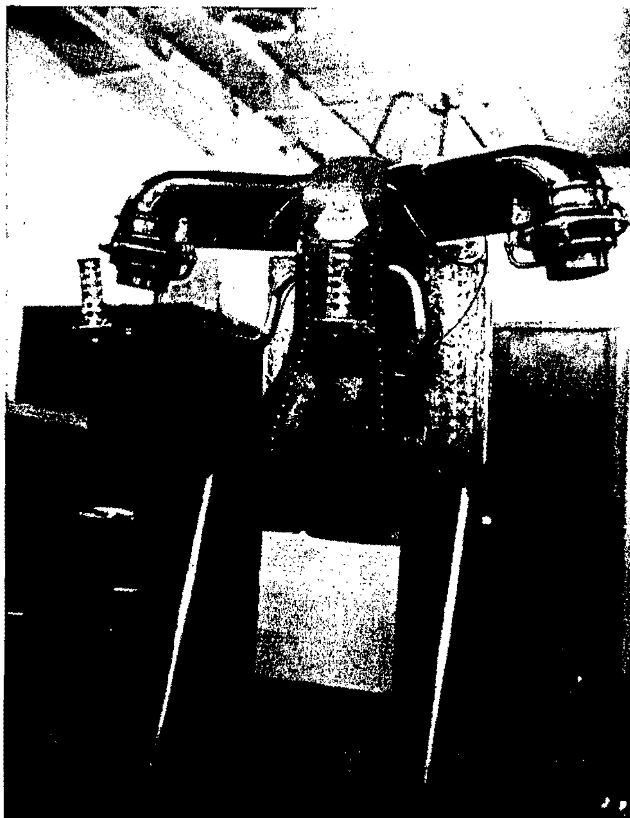
The first Jet Belt System was completed. It was delivered to Williams Research for the purpose of mating the engine to the system. (See accompanying photos.) Although no serious interface problems were discovered, there were three areas requiring some modest rework. Two of these are portrayed in Figures 1 and 2. The proximity of the oil-air separator to the vertical web on the back of the corset is shown in Figure 1. The clearance is about 1/16 inch which is considered minimal. A slight rework of the web and back-up metal angle will improve the condition considerably with no loss in structural integrity of the web.

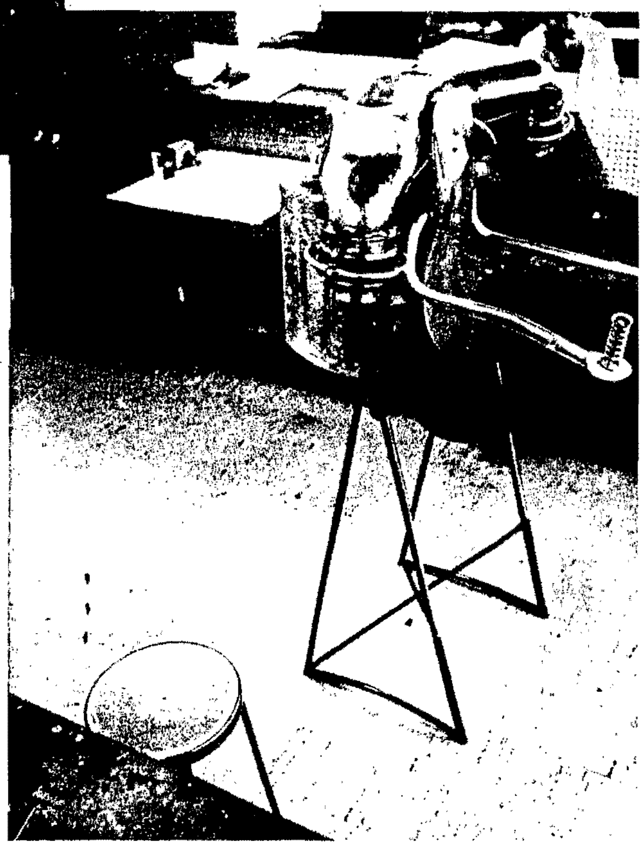
Figure 2 shows the fuel controller outlet line actually contacting the engine air inlet as well as its closeness to the triangular mounting pad for the oil lines for the first bearing





Assembled Individual Lift
Device at
Williams Research





Assembled Individual Lift
Device at
Williams Research

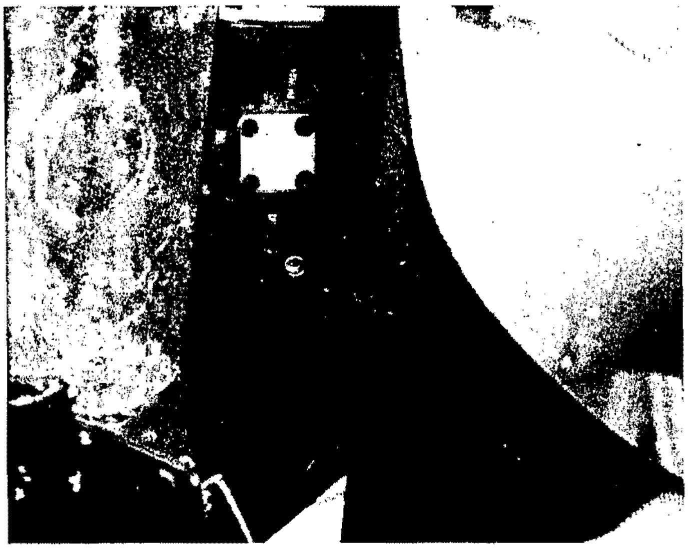


Figure 1. Oil Pump - Corset Web Interference

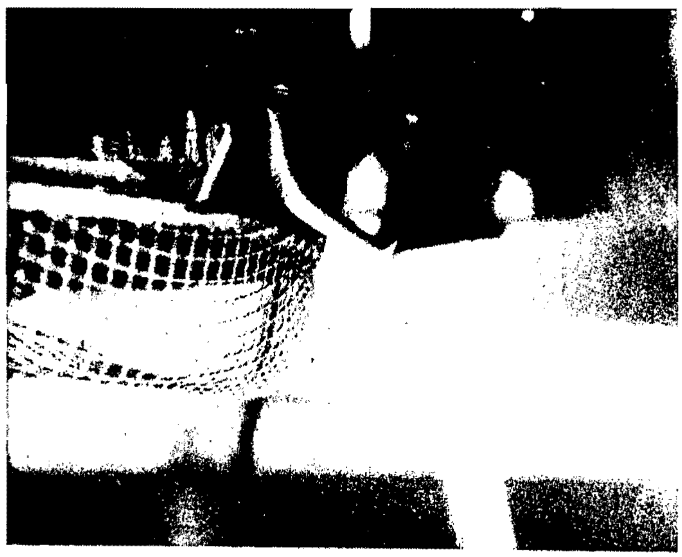


Figure 2. Fuel Outlet Line Interference

housing and quill shaft. Replacement of the union at the fuel controller outlet by a standard right angle bulkhead fitting will eliminate both these conditions. Discussions between Bell and Williams engineering resulted in the decision to make this change.

A mismatch was realized in the stand-offs at the lower portion of the fuel tank. This was caused by the fact that the mockup had been used to locate the stand-offs as well as the bolt holes for their attachment to the engine. Slight differences between the mockup and engine were sufficient to cause the mismatch and will require remaking the bracket part of the stand-offs.

The second bifurcated duct and nozzle assembly is nearly complete. Assembly progressed at a more rapid pace than the first one by virtue of familiarity with the fixtures and required, unique welding techniques. Completion of this major subassembly will enable the assembly of the second Jet Belt System to the degree possible with parts fabricated.

STARTER CARTRIDGE

Discussions were held with chemical and metallurgical engineers at Bell regarding a proposed alternate booster with less corrosive tendencies. This alternate booster did contain a small amount of lead compounds, and it was noted that at high temperatures lead will tend to cause inter-granular corrosion especially in temperature resistant metals. This intergranular corrosion can cause embrittlement of these high temperature metals.

Further study of this and other possible alternate booster substances is required and will be carried out in the future.

It should be mentioned again at this time that substitute materials for the igniter system have been selected as the result of a survey conducted at Bell. No tests have been conducted as yet to determine the actual durability under the specific conditions encountered during cartridge firing.

DEMONSTRATION FLIGHT TEST INSTRUMENTATION

(a) Communications

Representatives of the communications vendor are scheduled to visit Bell on October 17th for the purpose of testing a modified two-way communication system. The modifications entail the use of a noise shielded microphone as well as a bone conducting microphone. As before, tests will be performed on the Rocket Belt.

(b) Instrumentation

Instrumentation for use during the Jet Belt System tests in the engine test cell at Williams is being fabricated. The temperature and pressure probes presently being employed in the straight tailpipe at the engine mixing plane are being duplicated for installation in the bifurcated duct. In addition, total pressure rakes for surveying the nozzle exits, potentiometers for measuring nozzle deflection, and thermocouples for obtaining duct wall temperatures or exhaust gas temperatures are being fabricated.

Quotes have been received from two of the four vendors contacted regarding in-flight telemetering systems. One of these two will satisfactorily meet the Jet Belt requirements. The remaining two vendors will be contacted to ascertain their position relative to answering the request for quote.

ENGINE SUBCONTRACT PHASE II

ENGINE DEVELOPMENT TESTING

Mechanical Development (Performance Engine)

As of the end of August, the engine had made 3 test runs at speeds up to 38,000 RPM for a total running time of approximately 25 minutes. No problems had yet been encountered.

On Tuesday, September 5, two short duration runs were made made with a modified burner cover. These runs were curtailed because of unstable combustion. Since an improved burner configuration had been developed on the burner test rig, the decision was made to immediately incorporate the change into the engine. The engine was removed from the test cell on Tuesday afternoon, disassembled and reassembled with the new burner hardware that night and reinstalled in the test cell the next morning.

Attempts to light the engine on Wednesday, September 6, were unsuccessful. The igniter was altered on Thursday morning and this was followed by three successful test runs. The first run lasted about 5-1/2 minutes and was terminated to permit an adjustment to the cell furnished oil scavenge system. The second run was of 40 minutes duration, during which time two complete performance data points were obtained. The third run lasted about 31 minutes and provided two more data points. The only problem encountered was excessive leakage in the external oil system. There was evidence of some combustion instability in the lean burning range, but this was being worked out on the burner test rig. Maximum high pressure shaft speed attained during this series of tests was about 46,000 RPM.

On Friday, September 8, one more test run was accomplished. Duration of this run was 28 minutes, during which time one more data point was taken at 48,200 RPM. Following this run, the engine was disassembled for examination and incorporation of a burner change. The only discrepancy revealed by the teardown was evidence of excessive metal temperatures on the burner cover. This was anticipated because of test rig results and was, in fact, the primary reason for the teardown and inspection.

The engine was re-assembled with a modified burner and another test run was made on Wednesday, September 20. One complete data point was taken and one abbreviated point was obtained at 51,000 RPM. Shutdown was occasioned by an overheated bearing at 52,900 RPM. During the subsequent teardown, two modifications were incorporated to improve the bearing lubrication and sealing provisions. Instrumentation was also added to monitor certain pressures and temperatures which might influence bearing operation.

On Tuesday, September 26, three more test runs were made. One of these runs was witnessed by the attendees of the program briefing which was held at Williams Research Corporation on that day. These tests provided a total of 8 more performance data points, three of which were abbreviated because of the recurrence of the bearing overheating problem. The last run was terminated when the bearing temperature became critical at about 52,000 RPM.

The engine has since been disassembled for examination. No parts were damaged. The overheated bearings will be replaced, although they are still usable and will be saved for possible re-use. During this present teardown, several changes are being made to the lubrication system to eliminate the bearing overheating problem and, in addition, the radial compressor rotor face clearance is being decreased to improve the high pressure compressor performance.

These modifications to the performance engine hardware should be completed by Friday, October 6. It is expected that the engine will be ready for installation into the test cell on Tuesday, October 10, immediately upon removal of the endurance engine after its green run.

As of the end of September, the performance engine has accumulated 26 starts and 7.1 hours of operating time. The small number of relatively minor mechanical difficulties, in combination with the excellent aerodynamic performance manifested to date, has been very encouraging.

Performance Evaluation

Overall performance characteristics of the WR-19 engine are graphically presented in the accompanying Figs. 1 through 8. Test data points are shown alongside the predicted curves for convenience of comparison. A cursory look at these performance curves immediately reveals that the engine is exceeding expectations in the low speed range. There are, however, indications that the test data curves are converging with the predicted curves and would intersect below the design point if no performance improvements were made.

Corrected thrust, as shown in Figure 1, is substantially higher than predicted at low speeds and appears to be approaching the design level at design speed. The high thrust level results primarily from the higher than predicted inlet airflow (Figure 8), turbine inlet temperature (Figure 4), L.P. compressor efficiency, and turbine efficiencies. Failure of the thrust level to maintain its margin above the predicted curve is apparently due to the fact that L.P. compressor efficiency is maximizing well below the design point (as it did during rig testing) and also to the deficiency in overall compressor pressure ratio as shown in Figure 6. Peaking of the L.P. compressor efficiency below the design point was anticipated and no changes are planned to attempt to alter this characteristic because the efficiency should not drop appreciably below the design value of 84.6%. It is anticipated that the deficiency in overall compressor pressure ratio will be corrected by the decrease in impeller face clearance which is being incorporated in the next build of the performance evaluation engine.

Specific fuel consumption, shown in Figure 2, is well below the predicted level, and the curve shows a tendency to be flatter than predicted at off-design speeds. The reasons for this are precisely the same as presented in the preceding discussion regarding the characteristics of the thrust curve.

It is expected that inlet airflow, presented in Figure 8, will fall below the predicted curve in the higher speed ranges. This assumption is based upon axial compressor test rig results, wherein the compressor failed to pass the full design airflow in the high speed range. It has been previously reported that it may be necessary to increase the L.P. spool operating speed to achieve full design airflow if such is required to attain rated thrust.

This is permissible from a stress standpoint and can readily be accomplished by increasing the propelling nozzle area. The relationship between the LP and HP spool speeds, shown in Figure 7, reveals that the L.P. spool is running somewhat slow with the present

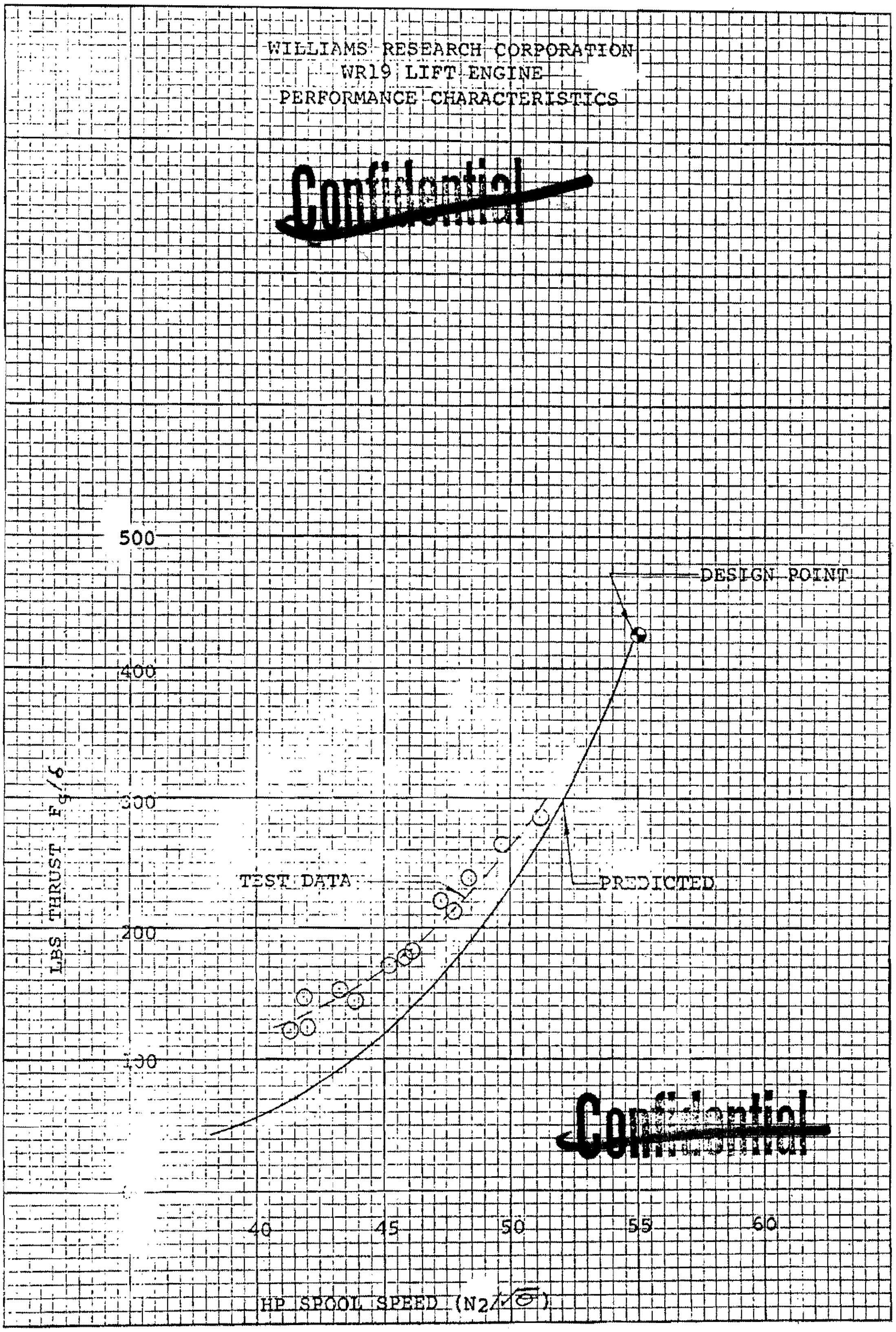

WILLIAMS RESEARCH CORPORATION
WR19 LIFT ENGINE
PERFORMANCE CHARACTERISTICS
Confidential
500
400
300
200
100
LBS THRUST F/δ
DESIGN POINT
TEST DATA
PREDICTED
Confidential
40
45
50
55
60
HP SPOOL SPEED (N2/√θ)

FIG. 1

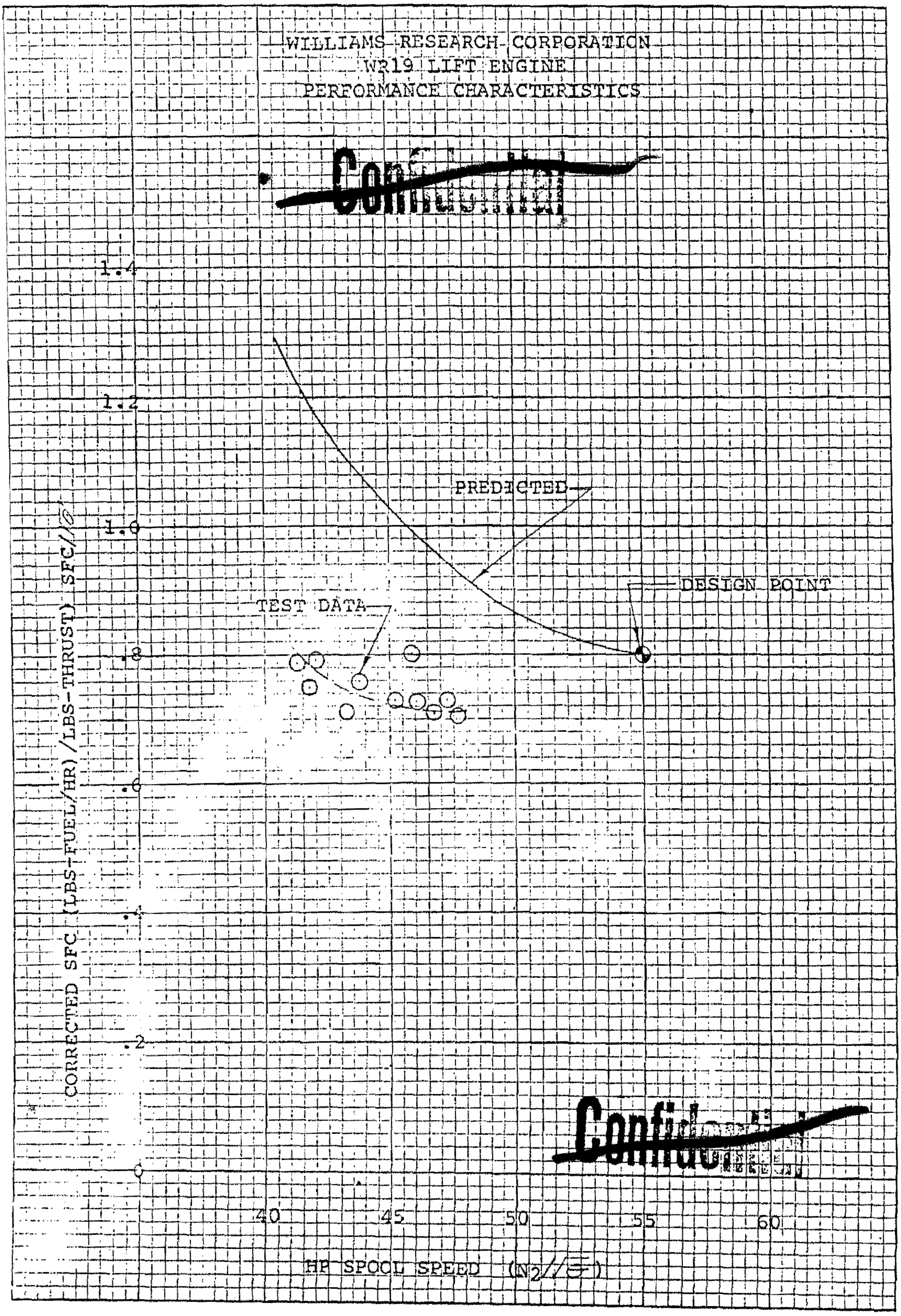


FIG. 2

[redacted]

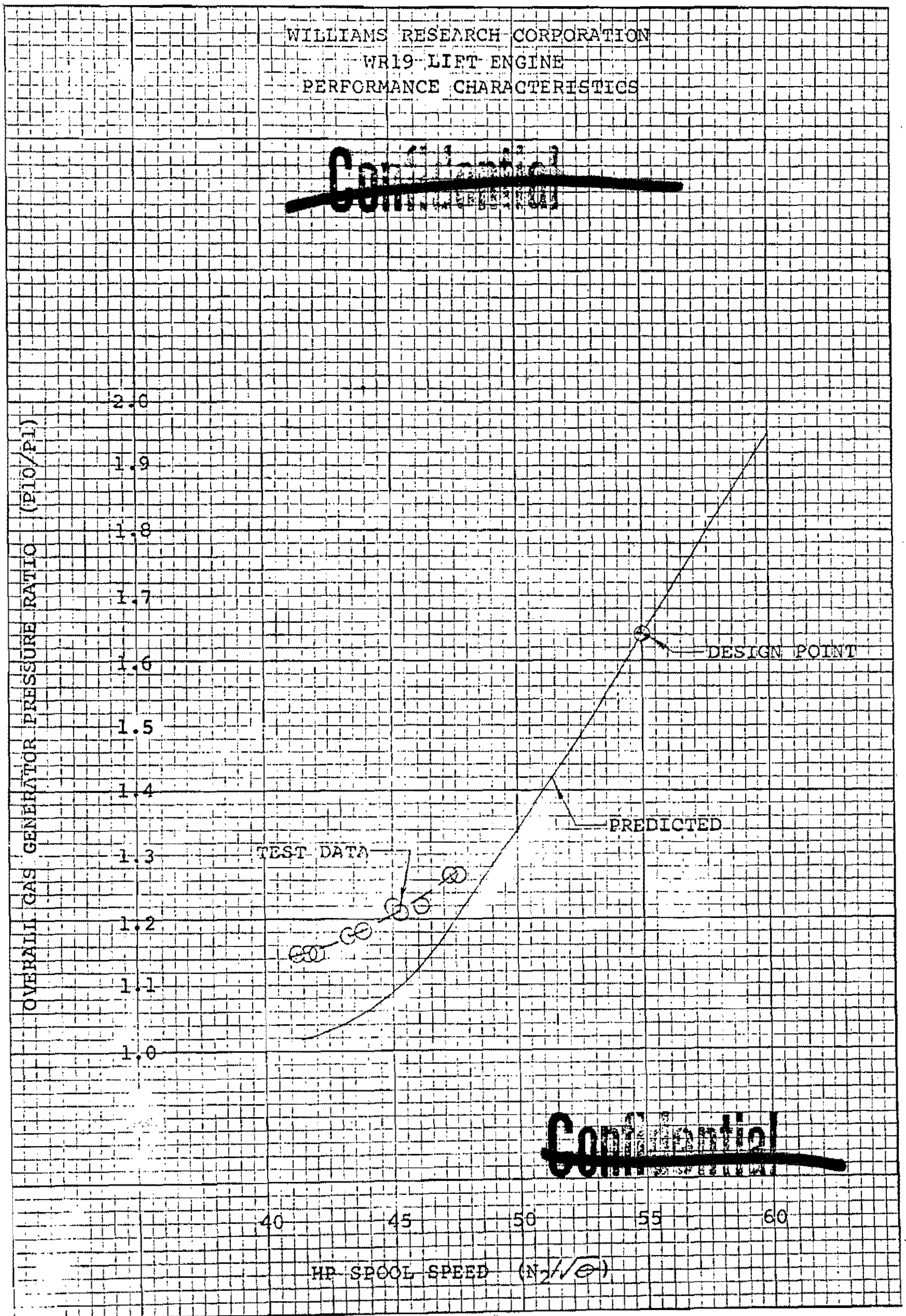

WILLIAMS RESEARCH CORPORATION
WR19 LIFT ENGINE
PERFORMANCE CHARACTERISTICS
Confidential
OVERALL GAS GENERATOR PRESSURE RATIO (P10/P1)
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
DESIGN POINT
PREDICTED
TEST DATA
Confidential
40
45
50
55
60
HP SPOOL SPEED

FIG. 3

UNCLASSIFIED [redacted]

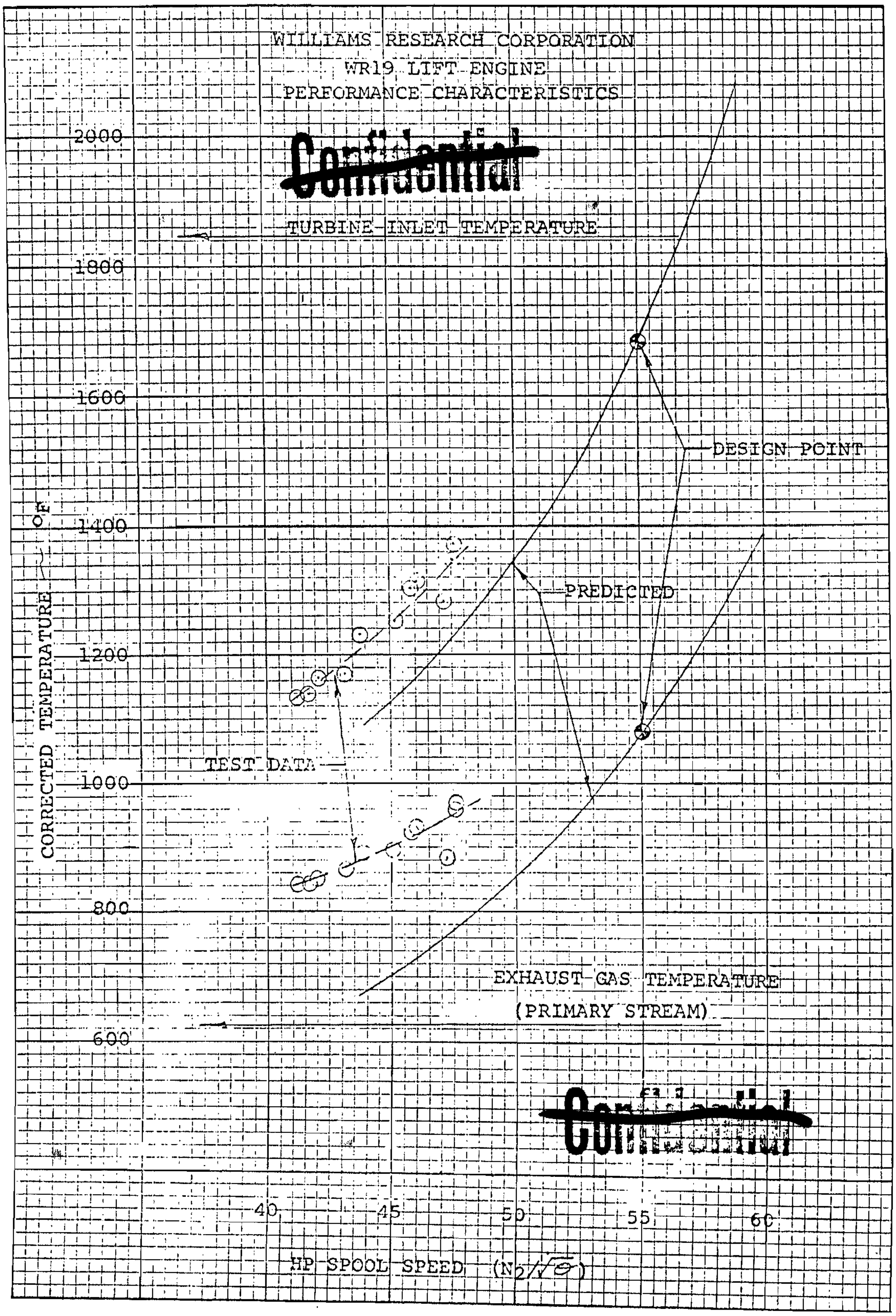


FIG. 4

UNCLASSIFIED [redacted]

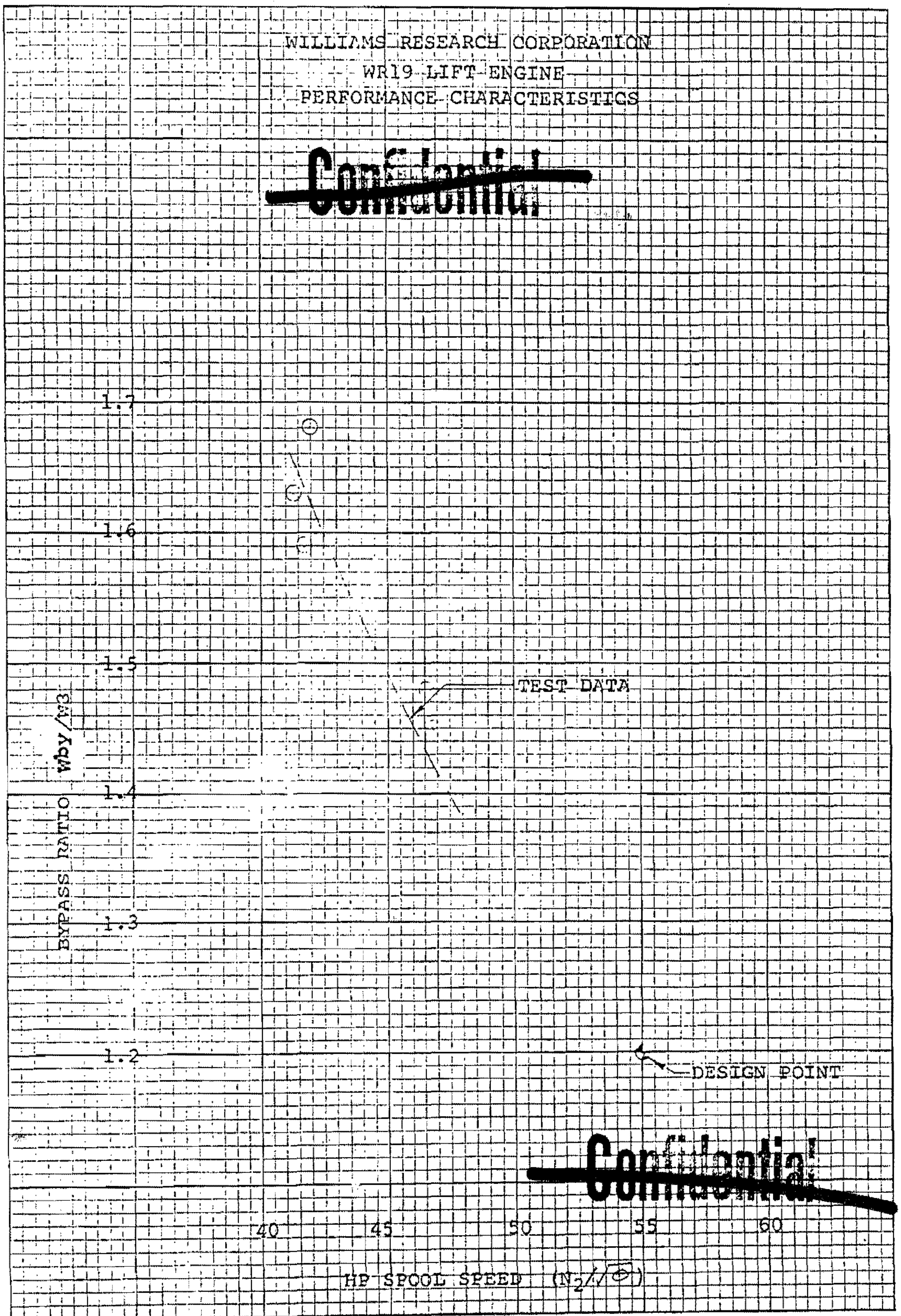

WILLIAMS RESEARCH CORPORATION
WR19 LIFT ENGINE
PERFORMANCE CHARACTERISTICS
Confidential
1.7
1.6
1.5
1.4
1.3
1.2
BYPASS RATIO Wby/W3
TEST DATA
DESIGN POINT
Confidential
40
45
50
55
60
HP SPOOL SPEED (N2/√θ)

FIG. 5

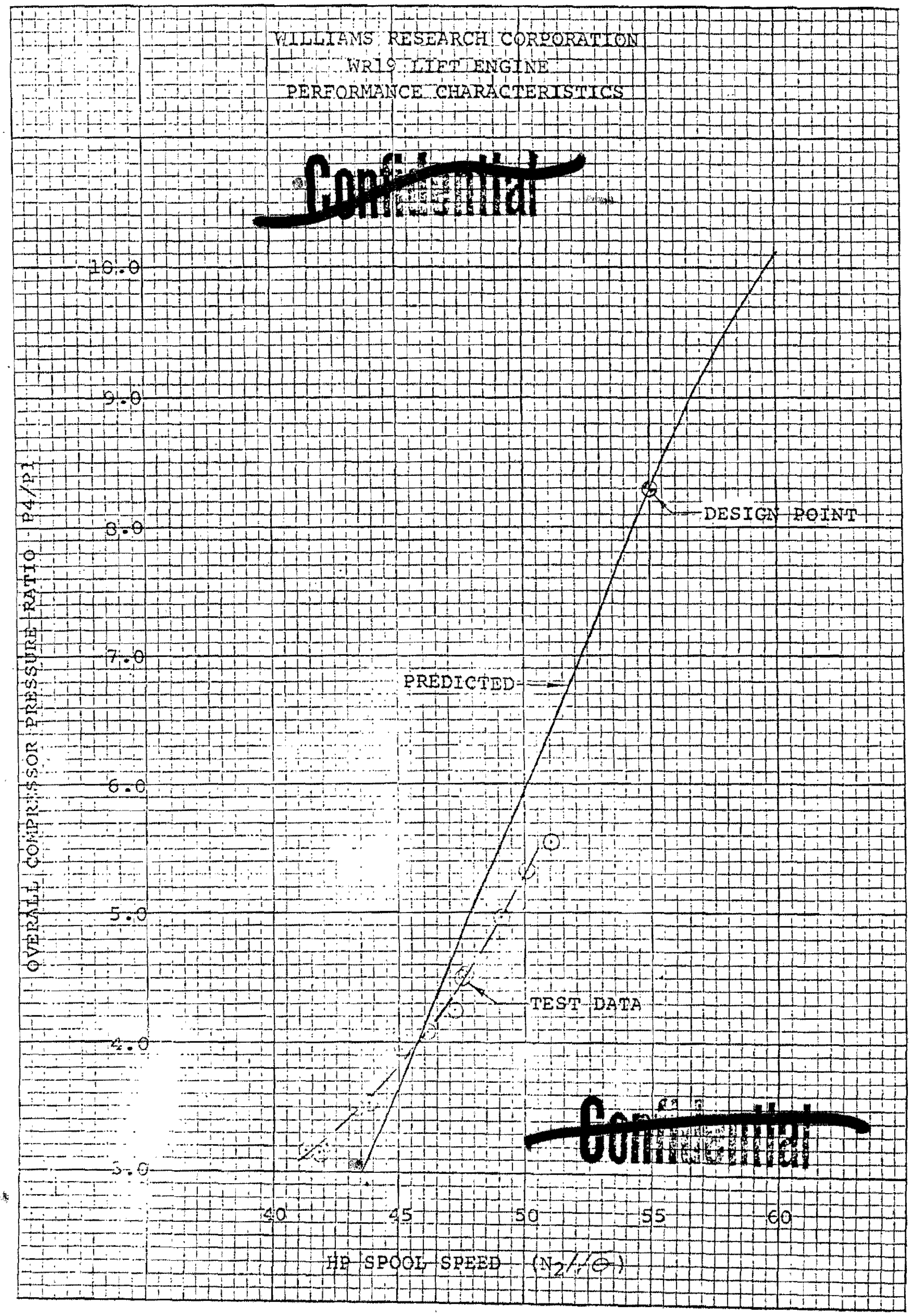

WILLIAMS RESEARCH CORPORATION
WR19 LIFT ENGINE
PERFORMANCE CHARACTERISTICS
Confidential
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
OVERALL COMPRESSOR PRESSURE RATIO P4/P1
DESIGN POINT
PREDICTED
TEST DATA
Confidential
40
45
50
55
60
HP SPOOL SPEED

FIG. 6

UNCLASSIFIED [redacted]

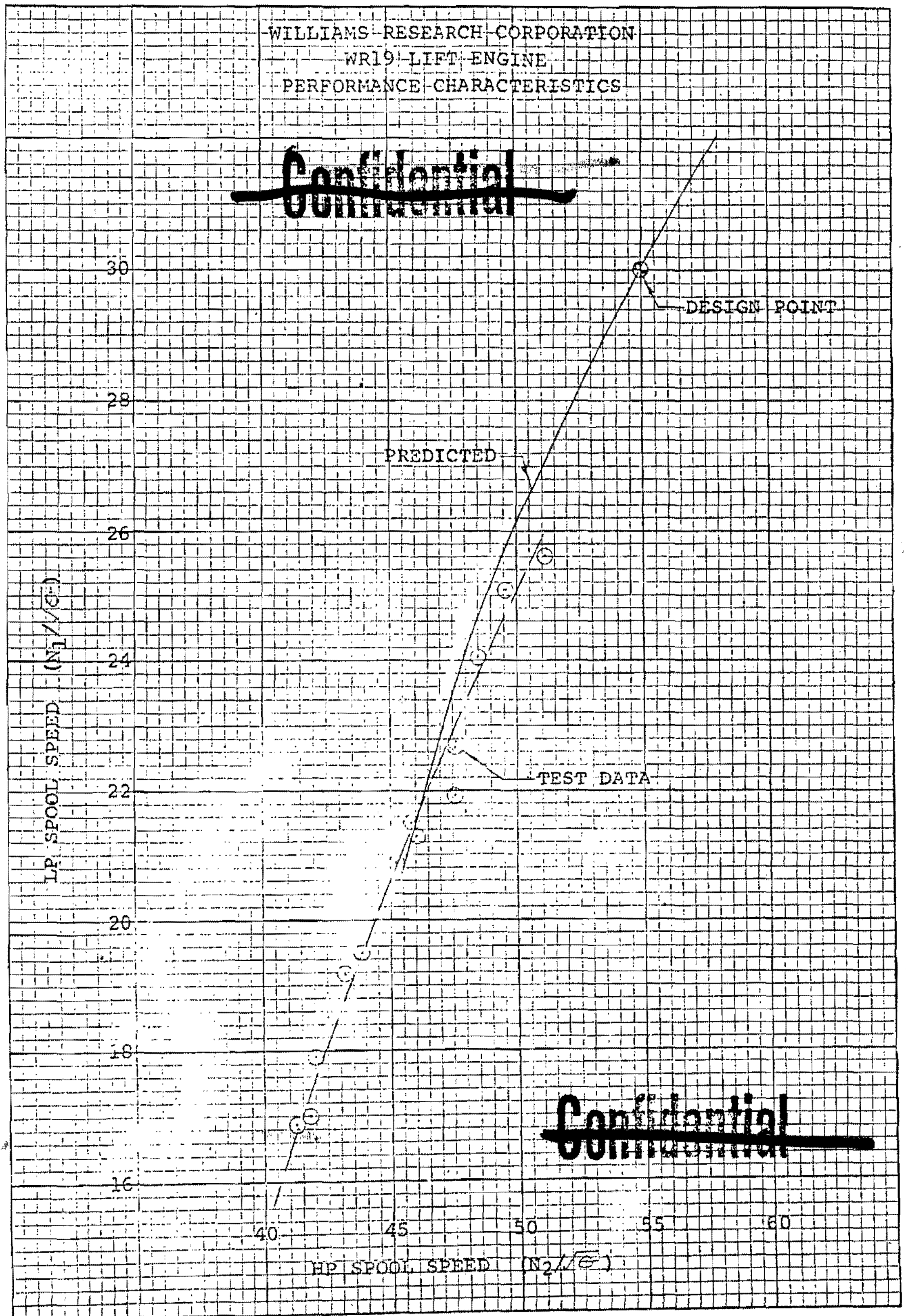


FIG. 7

UNCLASSIFIED [redacted]

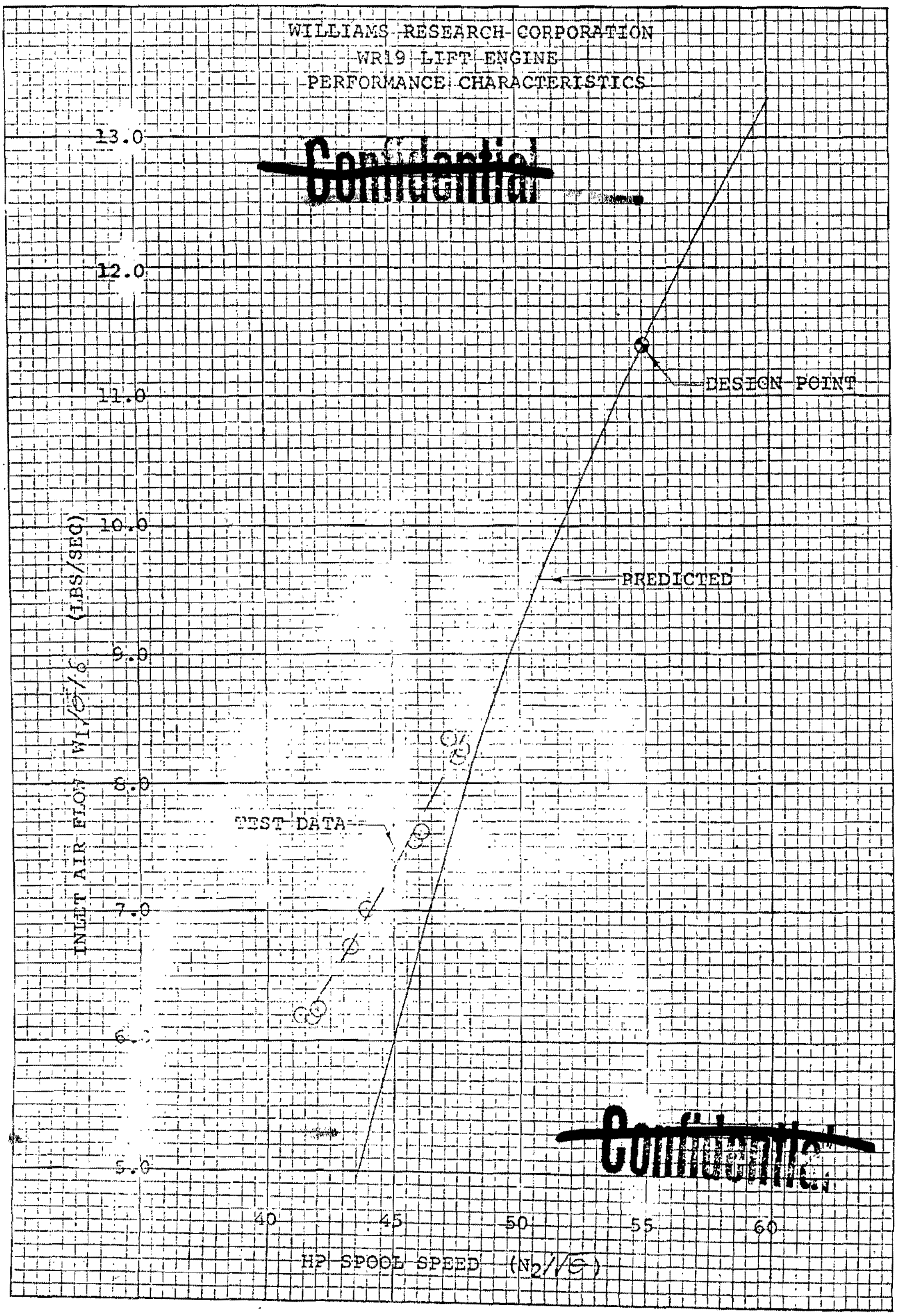

WILLIAMS RESEARCH CORPORATION
WR19 LIFT ENGINE
PERFORMANCE CHARACTERISTICS
Confidential
13.0
12.0
11.0
10.0
9.0
8.0
7.0
5.0
DESIGN POINT
PREDICTED
TEST DATA
INLET AIR FLOW (LBS/SEC)
40
45
50
55
60
HP SPOOL SPEED
Confidential

FIG. 8

exhaust nozzle. It appears that a nozzle area change is in order, but this will not be incorporated until further performance testing has been accomplished because of the difficulty this could cause in correlating various test runs and evaluating other changes.

Engine Test Cell Installation

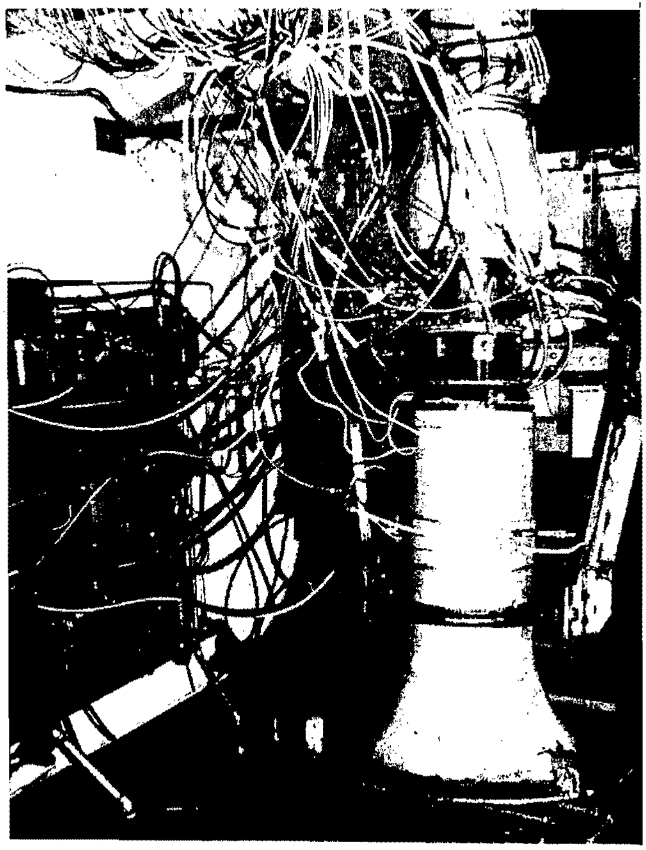
A picture of the performance engine installed in the test cell with all instrumentation hooked up is shown on a subsequent page.

BURNER COMPONENT TESTING

Burner development on the component test rig has been actively and successfully pursued during the past month to the extent that a modified and improved burner configuration has been available for incorporation during each engine teardown.

Emphasis has been placed upon developing a configuration which operates over a suitable range with reasonable metal temperatures because these are the parameters which have the immediate potential for restricting further engine development work.

On September 23, a combination of modifications to the burner cover, burner primary plate, and the fuel slinger provided the desired result. Metal temperatures were drastically reduced and lean burning characteristics were maintained. Circumferential gas temperature distribution and burner efficiency, however, were somewhat impaired. This configuration has not yet been incorporated in the engine hardware because of the extent of the modifications required. Development work on the burner test rig is continuing in an effort to optimize combustion efficiency and gas temperature profile before modifying engine hardware.



Engine Installed in Test Cell

ENGINE HARDWARE FABRICATION

Second (Endurance) Engine

The air inlet assembly and the fourth stage stator/transition/diffuser section were completed during September, and assembly of the engine was started. A preliminary assembly was accomplished for engine/jet belt mating tests for purposes of identifying any interference points. At that time, there were still several fit-up problems and documentation of the build (running clearances, etc.) was yet to be achieved. During the down time period of the performance engine, effort has been concentrated upon the assembly of the second engine. It is currently anticipated that assembly will be completed on Thursday, October 5 and that the first run will occur on Monday, October 9. Second engine availability, approximately two months behind schedule, is pacing the engine development program and has caused an overall program delay as discussed later in this report.

Third and Fourth Engines

As mentioned in last month's progress report, all detail components, such as stampings and machined rings, have been released for fabrication. In addition, the following assemblies or final machined parts have now been released and are being fabricated.

1. First stage axial compressor stator.
2. Second stage axial compressor stator.
3. No. 2 bearing carrier assembly.
4. Heatshield assembly.

5. No. 1 bearing retainer assembly.

6. Inner bypass duct assembly.

7. All rotating components requiring curvic coupling machining.

All remaining brazed assemblies are being held pending possible development changes. Overall manufacturing lead times have been established and critical release dates identified to assure availability of these subassemblies in accordance with engines #3 and #4 need dates.

MISCELLANEOUS ACTIVITIES

Oil Pump Assembly

All components of the oil pump package were completed during the past month. Assembly was started on September 20 and is continuing at the present time on a low priority basis because the pump package will not be used until after the second engine is in operation. All components have been trial fitted to ascertain that there are no interferences. Oil sump assemblies are in stores and the oil to fuel heat exchangers have been received.

Bifurcated Exhaust System

Design of the necessary ductwork and brackets to permit engine operation with the bifurcated exhaust system was started on September 18 and completed on September 25 as necessary in accordance with the replanned program.

Fuel Control Bench Test

In order to minimize the time involved in adapting the WR-19 fuel control to the engine and engine test time lost in adjusting the WR-19 fuel control on the engine, it has been decided to pre-set it by using the existing WRC fuel control test facility. This necessitates the design and fabrication of certain adapters to permit mounting and driving of the WR-19 fuel control. Design of these adapters was started on September 25 per the revised plan and fabrication will start on October 5. This change in the overall development test program has permitted recovery of several weeks of the overall delay effected by late availability of the second engine.

ENGINE DEVELOPMENT PROGRAM STRETCHOUT

The second WR-19 development engine (endurance engine) is now approximately two months behind schedule due to manufacturing problems encountered in the 4th stage stator/transition/diffuser assembly late in the fabrication cycle. Based on the now expected availability of the second engine, all remaining engine development tasks have been carefully evaluated and replanned and the resultant overall effect on delivery of the first flight engine is 5 weeks slippage from previous plans. A portion of the lost time on the 2nd engine was recovered by the decision to accomplish fuel control adjustment on an existing WRC fuel control test facility rather than on the engine. Further time was recovered by readjusting several of the test objectives, the most significant is delaying the cartridge start demonstration tests until later in the program. The deliverable flight engines do not rely on use of the cartridge start system.

CONTRACTUAL STATUS

GENERAL

Fiscal and schedule status of the overall program are summarized subsequently in this section of the monthly progress report. During the reporting month, the objectives of the revised scope of work program were pursued in accordance with plans defined and verbally approved in March 1967.

At the request of ARPA, discussions were held with ARPA, AVCOM and AMC concerning current program status and projected costs to complete the revised scope of work. As a result, program plans, work statements, specifications and estimated costs to complete the program are being formalized and will be submitted to AVCOM leading to negotiation of necessary contract changes to recognize the revised scope of work program.

An additional $75,000 has been committed to the Individual Lift Device contract which increases cost limitations to $2,362,360 and assures continuity during the period of finalizing a contract amendment. It is estimated that the new funding will carry the program through 3 November 1967 in accordance with the present program plans.

PROGRAM PLAN

Engine performance development testing continued during the month with a new total of over 7 hours of running achieved on the engine. The engine has continued to operate relatively trouble free although a bearing lubrication problem was encountered in high speed runs. A series of burner improvements have been developed on the burner test rig and incorporated in the engine at successive teardowns. A final burner configuration although elusive appears near at hand. Achievement of a good combustor is expected this month after which the burner/slinger test stand will be used for development of a suitable catalytic igniter as described in the last monthly progress report.

The second engine (endurance) is not fully assembled and is now approximately two months behind schedule. Contrary to the last monthly progress report it is now pacing the engine development program and will cause a 5 week delay in availability of the first flight engine. The last remaining sub-assembly is available and the engine is expected to be assembled and running early in October.

A significant milestone was achieved last month when the engine was mated with the first flight Jet Belt. Some minor interferences were encountered and are being rectified.

The remaining work in the current contract has been planned in detail and is summarized in the subsequent schedule with major milestones defined. The detail plan includes many minor milestone objectives to provide good program visibility and provide a good tool for monitoring and measuring program progress. It incorporates the effect of second engine delay.

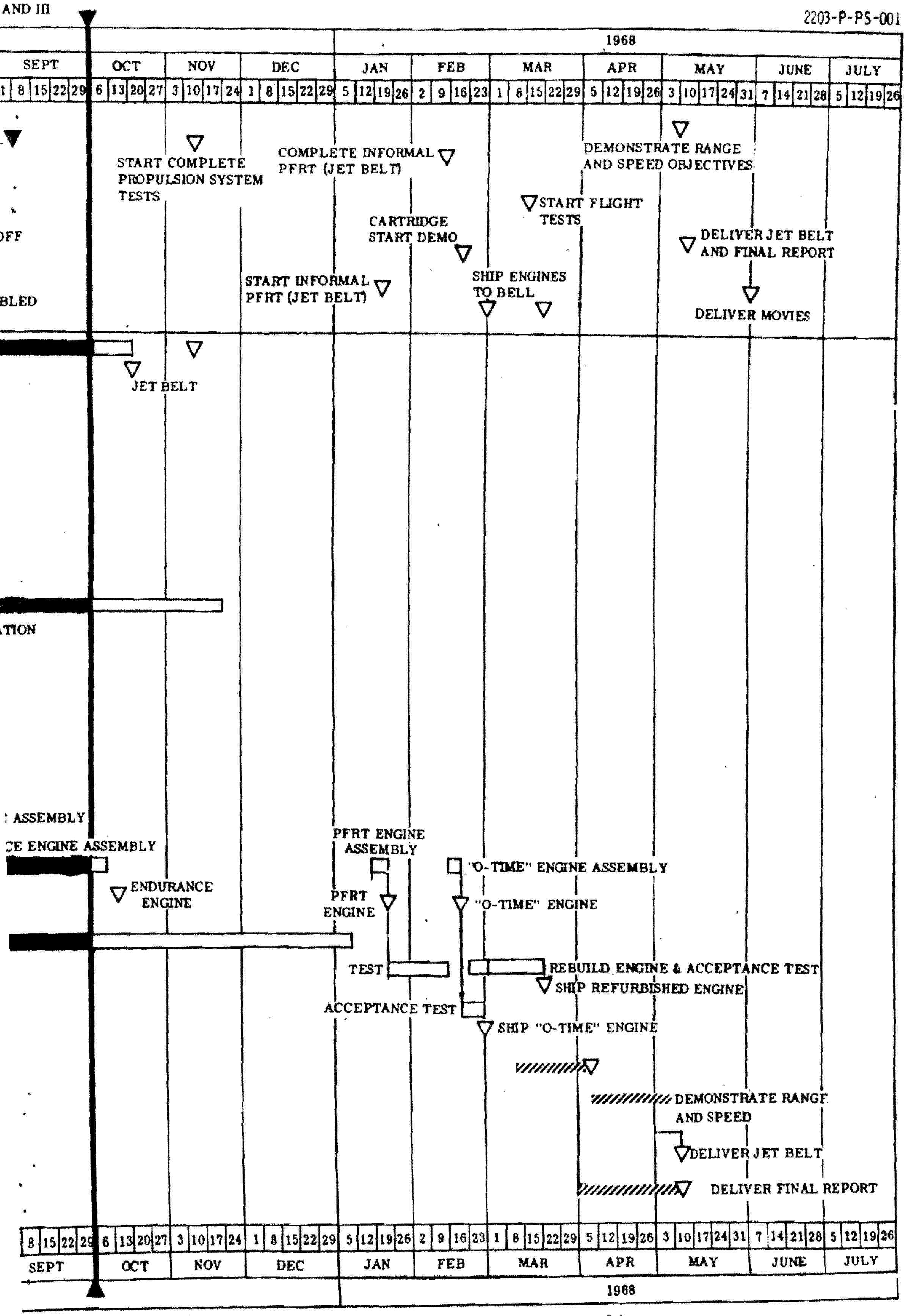
In planning the remaining work, it was possible to effect revisions in test planning and test programs which recovered three weeks of time caused by the second engine delay. The two primary areas of schedule recovery concern fuel control adjustment which was to be accomplished on the engine in the test stand and now will be achieved on an available specialized test facility; and cartridge start demonstrations on the test stand which will be accomplished later in the program after development testing is complete.

Complete propulsion system testing is now scheduled for early November with completion of all development testing scheduled for January 11, 1968. PFRT of the Individual Lift Device will now be completed in mid-February with delivery of the zero time first flight engine scheduled for 1 March 1968. Tether and free flight tests are planned to be accomplished in 7 weeks in the months of March and April.

Final report, hardware and specifications will be delivered by mid March and movies by the end of the month which will complete the current contractual requirements.

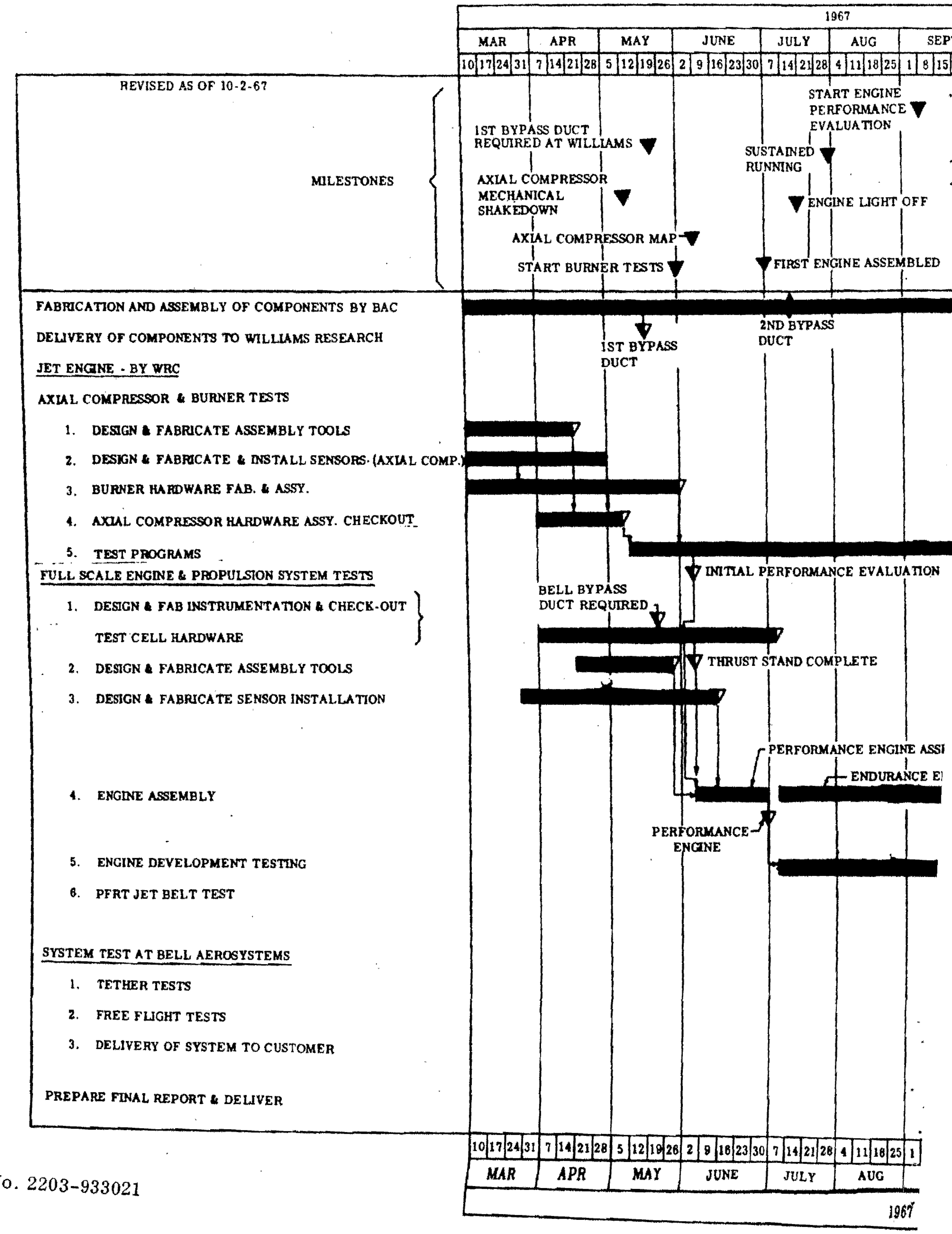
ICE PROGRAM PLAN
AND III

2203-P-PS-001



INDIVIDUAL LIFT DEVICE PR

PHASE II AND III



FISCAL

Fiscal status shown in the subsequent table is based upon costs and open commitments through September 29, 1967 which is the end of the accounting period. Based upon the new total cost limitation of $2,362,360 and liabilities as noted, approximately $84,635 remain as of the end of the period.

Engine Subcontract		
	Expenditures	$1,565,026
	Open Commitments	40,266
	Total Liability	$1,605,292
Bell Aerosystems		
	Expenditures	$ 672,433
Total Prime Contract Costs		$2,277,725
Present Cost Limitation		$2,362,360
Remaining Funds (9/29/67)		$ 84,635

ESTIMATED COSTS AT COMPLETION

As mentioned previously, a letter is being prepared for submittal to AVCOM summarizing the program costs to date and a projected cost at completion. The letter is based on the cost estimate to complete the revised scope of work program which was discussed briefly in the last monthly progress report.

Subsequent to the last progress report, overall program status was reviewed and remaining tasks planned in detail. After careful review and replanning, it is now evident that late availability of the second development test engine (endurance) has necessitated a 5 week stretchout in the program and has attendant cost increases.

The estimated costs associated with the 5 week delay are approximately $50,000. This new increase along with the cost information reported last month form the basis for the letter to be submitted.

It is anticipated that the necessary contract revisions will be finalized during the month of October and will be reported in the next monthly report.

FUTURE PLANNING

A proposal for a 13 month follow on program to continue development of the overall Individual Lift Device or Individual Mobility System development was submitted to AVCOM and ARPA during the month. The primary objectives of the proposed follow on effort are to conduct the necessary systems analysis, cartridge start/engine durability testing and engine component development, all leading to definition of the optimum system for qualification and introduction to service in subsequent phases. The current contract defines a feasibility demonstration program and as such precludes the systems engineering systematic development approach to an operational system. In order to assure continuity in the overall program, this new work must be initiated early in the next calendar year.

The proposed follow on effort encompasses 6 major tasks, which have many interfaces and interactions although presented as individual items of work. Individually they account for developing required thrust levels, self contained start capability and flight characteristics as well as providing reliability, maintainability, human factor and training analyses and trade studies for definition of an effective operational system. Collectively the six tasks constitute a systematic analytical, and development effort to expand

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Task I - Cartridge Start System Development and Turbine/Burner Improvement

One of the fundamental requirements of an Individual Mobility System is self contained starting to divorce the system from ground equipment thereby providing more flexibility in operation.

The current contract requires demonstration of the ability to start the WR-19 engine using a self contained cartridge start system. This system, chosen because it is the lightest weight source of high energy for engine start and is highly compatible with field operation, exposes certain engine components to severe environmental shock and a somewhat (although small) corrosive atmosphere. The present WR-19 engine was designed and built to withstand these conditions.

This proposed task entails conducting bench tests of comparative cartridges and accomplishing cartridge starts (400-600) on one of the development engines in order to determine the effects of cartridge start on engine durability and develop engine life characteristics consistent with operational objectives.

In addition, because the cartridge start testing requires operating the engine, it is proposed to improve turbine section efficiency and increase burning temperatures during this running. These engine thrust improvement efforts are included in this task rather than Task II Component Improvement because they require development on a running engine rather than on a test stand. The

The increased temperature is consistent with other Williams Research Engines and the goals for turbine efficiency appear achievable with a general tightening of that section of the engine.

Task II - Axial and Centrifugal Component Development

Operational studies carried out by Bell in parallel with the current contract effort indicate that an increase in engine thrust is necessary to account for special payloads and desired altitude/temperature take-off conditions.

This proposed task consists of test stand development of both the axial and centrifugal compressor efficiencies with modest improvements established as goals and all well within current technology and less than those achieved in some contemporary engines.

Task III - Flight Testing

The current contract limits flight testing to demonstration of contract objectives of range and speed, and limited instrumentation is planned. This proposed effort will conduct flight testing to develop performance, handling qualities and maneuverability of the Individual Lift Device being developed in the present contract. These data are extremely necessary for any subsequent redesign for operational use.

Task IV - Human Factors, Engineering Development and Flight Test Program

Although a considerable amount of man/machine inter-relationship information and fundamental human factor data will be available from the present contract flight demonstration, basic system studies and analyses will not be achieved. The concept of the Individual Mobility System presents a new and unique human factor problem. The present feasibility device has been treated intuitively based on rocket belt experience. By analysis and flight test, the proposed work in this task will develop the true man/machine relationship and define necessary human factor considerations and criteria for subsequent operational system design.

Included also in the study will be preliminary definition of operator selection criteria and training requirements.

Task V - System Reliability Development Program

This task includes a failure mode analysis, system and sub-system reliability analysis, statistical evaluation of all test data to date and establishment of reliability goals for components, sub-systems and systems consistent with operational requirements. A reliability test plan will be outlined to define qualification testing of the Individual Mobility System in subsequent phases. It is through this systematic analytical approach in the proposed follow on work that reliability can be given proper emphasis in any subsequent system redesign and assure achieving the high reliability goals required for an operational system.

Task VI - System Maintainability Development Program

The present contractual effort will provide preliminary maintenance and inspection procedures suitable for the feasibility flight program. By nature of the contract objectives, maintainability was not given detail consideration. This proposed follow on task will define a basic maintenance concept consistent with the intended operational use and will analytically develop maintenance requirements for consideration in system redesign in a subsequent phase. The study will develop operational cost data and will provide baseline data for operational procedures concerning logistics, maintenance, inspection, overhaul, training and other associated aspects necessary for operational use of the system. Performance of a sound maintainability study as proposed in the follow on phase to the present contract assures that proper consideration will be given to this important area in any subsequent redesign.

VISITS

The following visits were made in support of the contract during the reporting period.

(3)	Williams Research	Detroit, Michigan	Monthly Review of Engine Program
(1)	Williams Research	Detroit, Michigan	Review and Discuss Engine Replanning
(2)	Williams Research	Detroit, Michigan	Program Review
(1)	AVCOM	St. Louis, Mo.	Discuss Contract

VISITORS

On September 26, at the request of AVCOM, a program review was conducted at Williams Research Corporation during which the status of the overall Individual Lift Device contract was reviewed; the performance engine was run; the first complete Jet Belt was displayed after engine mating tests; and the proposal for follow-on development work was discussed in detail. The following visitors were in attendance:

ATTENDEE	REPRESENTING
Maj. H. A. F. Benson	Australian Embassy
Cdr. A. J. Bastick	British Embassy
Lt. Col. William A. Ackerman	USAMC
Lt. Col. John D. Kennedy	USACDC Inf. Agency
Maj. Cyril R. Morgan	Canadian Army - Liaison Officer ATAC
Mr. A. N. Tedesco	ARPA
Dr. Kenneth Campbell	IDA - Consultant
Maj. Peter G. Cei	CDC Liaison Officer - ATAC
Mr. Albert F. Bird	ATAC
Mr. R. T. Alpaugh	AMCRD-GP
Mr. Earl Gillis	USAVCOM

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6	Battelle Memorial Institute 505 King Avenue Columbus, Ohio 43201 Attention: RACIC
7	U. S. Army Material Command Room 2048 Gravelly Point Washington, D. C. Attention: AMCRD-F Mr. Ken Kasai
8 9 10	Director of Advanced Research Project Agency (ARPA) Pentagon, Room 2B286, Washington, 23, D. C. Attention: Dr. C. J. Wang
11	Director of Advanced Research Project Agency (ARPA) Pentagon, Room 3D160, Washington, 23, D. C. Attention: Mr. A. Tedesco
12	OCRD - Room 3D432 The Pentagon Washington, D. C. Attention: L/Col. Phillip Feir
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15 CIA
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Washington, D. C. 20505
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16 Institute for Defense Analysis
400 Army-Navy Drive
Arlington, Virginia 22202
Attention: Dr. Kenneth Campbell

17 ATAC - RMSTA - HL
Warren, Michigan
Attention: Mr. A. F. Bird

18 U. S. Army Material Command
Gravelly Point
Washington, D. C.
Attention: AMCRD-GP
Mr. R. T. Alpaugh

19 AFFDL (FDV)
Wright Patterson Air Force Base
Ohio
Attention: Daniel E. Fraga

20 CDCMR-O
Ft. Belvoir
Virginia
Attention: L/Col. Wm. Tedesco

21 CDC Infantry Agency
Ft. Benning, Georgia 31905
Attn: CM Division
Lt. Col. Kennedy

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Individual Lift Device

BELL AEROSYSTEMS CO BUFFALO NY

15 DEC 1968

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INDIVIDUAL LIFT DEVICE (u)

CONTRACT NO. DA23-204-AMC-03712(T)

REPORT NO. 35

DECEMBER 15, 1968

BELL AEROSYSTEMS - A textron COMPANY

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BELL AEROSYSTEMS COMPANY

Division of Bell Aerospace Corporation
Post Office Box One . Buffalo, N.Y. 14240

(6)

INDIVIDUAL LIFT DEVICE (U) (8)

(14) BA-22Ø3-933Ø35 ~~REPORT NUMBER 35~~ ✓

(11) 15 Dec[redacted]68 (12) 39p.

(15) DA-23-204-AMC-Ø3712(T), ARPA Order-764

ARPA Order Number 764
Program Code Number...........................6G20(23)
Name of Contractor............................Bell Aerosystems Company
Date of Contract..............................30 December 1965

Contract Number...............................DA 23-204-AMC-03712(T)
Contract Expiration Date......................1 February 1969 (Revised)
Project Title.................................Individual Lift Device
Project Manager ....Robert J. May
Technical Director............................Robert F. Speth

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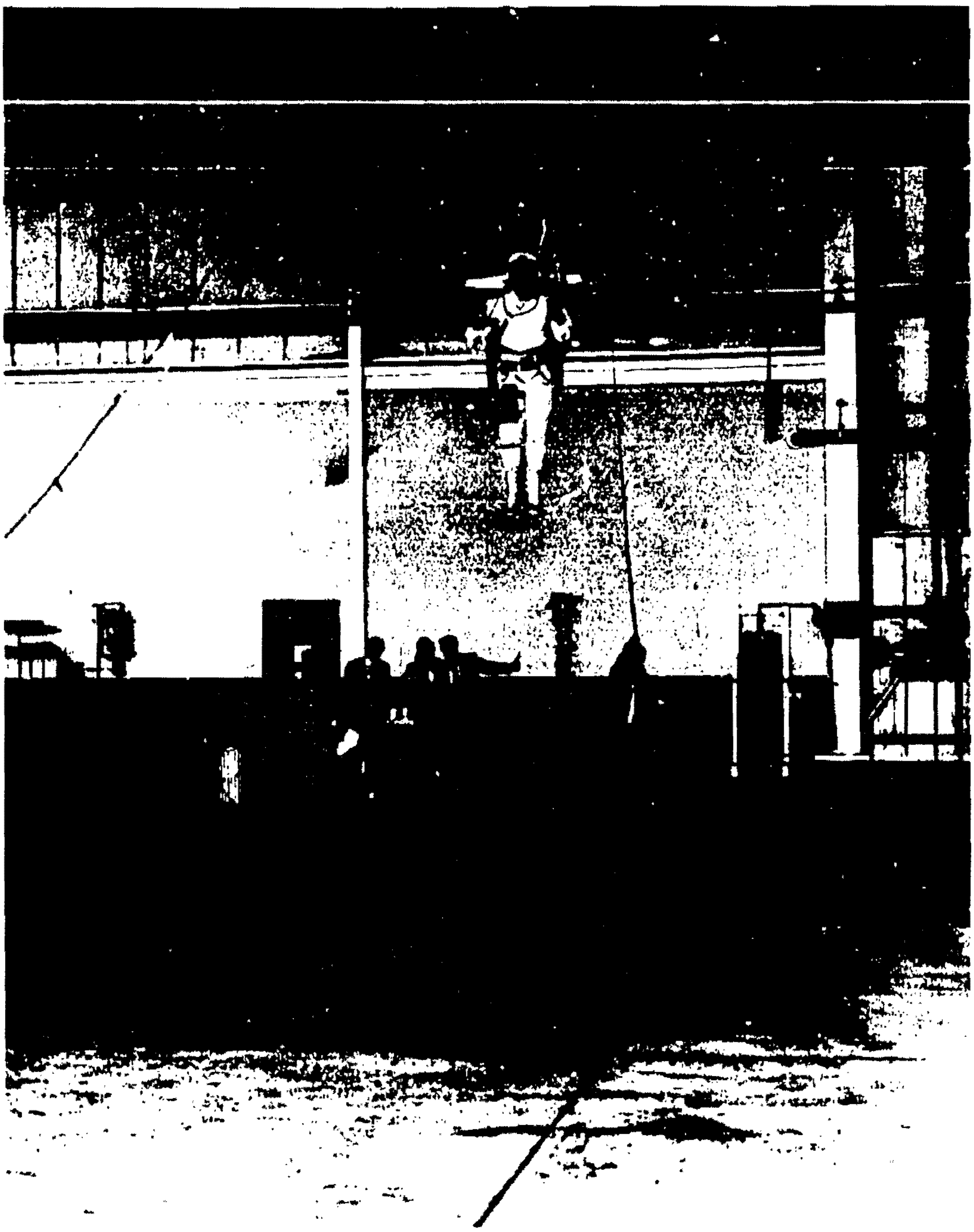

Report No. 2203-933035

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BELL AEROSYSTEMS COMPANY

INDIVIDUAL LIFT DEVICE

SUMMARY

(C) The Phase I design portion of the program was completed in approximately November 1966 and resulted in the Individual List Device configuration which is shown in the frontispiece (Jet Belt Flight). The engine is mounted inverted in a vertical attitude and exhaust gases are ducted through a rigid bifurcated duct system to nozzles located at the extremities and pointing downward. Nozzles are suspended from the duct by a bellows which permits deflection fore and aft and to the sides for control. Control inputs and engine throttling are achieved as in the rocket belt. Wrap around fuel tanks are used and are unpressurized. Design empty weight is 99 lbs. including the engine. With a 180-lbs. man, 25-lbs. payload, and 44 lbs. of fuel and oil, take off gross weight is 348 lbs.

(C) The engine which is 1 foot in diameter and 2 feet in length is a twin spool, bypass turbo jet engine with a minimum rated thrust of 425 lbs. The two spools are counter rotating to minimize gyroscopic forces during maneuvers. Design specific fuel consumption is 0.8 lbs. fuel/lb. thrust/hour. ~~Airflow is approximately 11.65 lbs./second.~~ Engine design weight is 60 lbs.

(C) Calculated performance indicates the Jet Belt can be flown to speeds over 100 miles per hour and to ranges of 10 miles.

(U) Phase II now in final stages entails fabrication, development testing, propulsion system PFRT and delivery of flight qualified hardware and overlaps the tether flight portion of Phase III. The overall program culminates with free flight testing in Phase III and demonstration of flight range and speed objectives.

[redacted]

(U) All Jet Belt hardware except for the PFRT engine and "0" time flight engine had been fabricated and an interface check was made in September when engine No. 2 was mated with the flight Jet Belt and the complete system was assembled for the first time.

(C) Both of the development engines have produced slightly above the contractual minimum rated thrust of 425 lbs. and have been repetitive. Indications are that the engine design cycle thrust of 470 lbs. could be achieved with minor internal modifications (Reference Bell Report No. 2203-950001). Both of the development engines were very close to the 60 lb. design weight at inception of development testing. Specific fuel consumption for both of the engines based on test data is 0.65 lbs. fuel/lbs. of thrust/hour at rated speed. This is considerably improved from the 0.80 lbs. fuel/lbs. thrust/hour design goal.

(U) Until mid-November, the development program was remarkably free of problems. During November, engine #1 suffered a fatigue failure of a bearing support and a hard axial rub was experienced on engine No. 2. A new bearing support was designed and subsequently proved acceptable during January operation of Engine #1. The axial rub in Engine No. 2 was caused by breakdown of an insulation material used to protect a bearing cavity from hot exhaust gases and has subsequently been corrected. During December, engine No. 2 was operated at reduced RPM due to its limited life bearing support (while engine No. 1 was being refurbished) and the fuel control was mated, adjusted and successfully operated during starting acceleration and deceleration. A minor engine fire due to an internal fuel line failure curtailed further running with engine No. 2.

It is noteworthy that despite the engine development problems encountered, there has not been a catastrophic failure with either of these two engines. Engine No. 1 ran for a considerable time after the bearing carrier support failed. Engine No. 2 continued to run until tests were terminated and engine disassembled for inspection of second stage nozzle turbine. In each case the engine continued to produce ample thrust to prevent a catastrophe if this had occurred in flight. Testimony to the ruggedness of the engine design, the significance of this to the Jet Belt concept is readily apparent.

Most of the running time during April and May was concentrated on resolution of air/oil separation problems which resulted in a large number of external and some internal lubrication system modifications. At the end of this period considerable progress had been made and an acceptable approach was resolved. Running during the early stages of these two months was hampered by erratic fuel control operation which was also undergoing several internal reworks. Toward the end of the period, the fuel control exhibited much more reliable operation. The primary trouble overall stemmed from the Roulon face plates used in the fuel pump. A reconfiguration to bronze face plates has been in work, bench tested and three controls are being reworked to this design. This fix has proven successful during subsequent engine testing.

At completion of development testing Engine No. 2 had 103 hours of operation and Engine No. 1 had 69 hours (at time of delivery to WPAFB). Engine No. 2 has accumulated 271 start cycles and Engine No. 1 has 100 starts for a cumulative total of 371 starts. Engine No. 1 and all necessary accessories, test equipment and operation and maintenance procedures were delivered to WPAFB early in August, all of which was on schedule or several weeks ahead of schedule. Test cell installation was delayed until October due to cell availability. Approximately 11 hours of run time has been accumulated to date on this engine at WPAFB providing test data for a series of attitude and Mach number conditions.

Engine No. 2 was delivered to Bell in July for ground effect and cross-wind inlet tests which were successfully completed in one afternoon. This was the first time the complete system was operated and the first time the WR-19 was operated outside of the test cell. The ground test program verified previous analyses and scale model tests for ground effect.

During the month of July, the engine program entered the flight engine acceptance test phase. As reported in that monthly progress report, late availability of several hardware items delayed assembly of the engine. Engine assembly was finally completed on 14 August and the initial "green" run or break-in run was accomplished.

On this run and several subsequent attempts to accomplish the "green" run and initial phase of the acceptance test, a number of problems were encountered. The most significant of these were erratic fuel control operation and a turbine failure due to a rub. The primary fuel control problem has been inability to obtain repeatability of the fuel flow scheduling. As a result of a minor internal rework consistent repeatability has been obtained on bench tests and the reworked control has operated the engine satisfactorily. The turbine tail shaft failure was induced by too thin a coating of flame spray material on one side of the labyrinth seal area in the No. 6 brazing support and exhaust duct assembly. The problem is

(U)unique to this particular unit (5 prior units were made without this condition) and steps have been taken to prevent reoccurrance.

(U) After the turbine tail shaft failure encountered during August, the entire engine was disassembled and each part thoroughly inspected. Engine No. 3 was then reassembled with turbine section parts scheduled for engine No. 4 and reentered acceptance testing on September 4th.

(U) Acceptance testing of Engine No. 3 (Flight engine) was completed and the engine delivered to Bell Aerosystems on 18 September.

(C) The engine thrust level at time of initial delivery was slightly below minimum rated thrust. On the last build prior to delivery, the engine produced a corrected sea level standard day thrust of approximately 415 lbs. at the governor speed of 53,450 RPM. This last test was made with a straight tail pipe and resulted in a delivered thrust at the bifurcated duct nozzles of approximately 375 lbs. of thrust. Engine SFC was approximately 0.66 lbs. fuel/lb. thrust/hour at governor speed and installed SFC (accounting for installation losses) was 0.70 lbs. fuel/lb. thrust/hour. The actual all up weight of the engine is 66.5 lbs. The weight increase over the design weight is attributed to (1) An increase in sheet metal parts and tube wall thicknesses in some areas of the engine over the original gage material used in the development engines. (2) The use of an engine mounted oil filter not in the original design (3) Heavier redesigned #4/5 bearing support over original configuration and (4) Reworks of several parts required because of manufacturing deviations peculiar to this set of engine parts.

(U) After receipt of the engine, four ground test runs were made at Bell to verify system operation and instrumentation. On Tuesday, September 24th, the tether test phase (Phase III) was initiated.

(U) It is worthy of mention that tether flights are in actuality free flights with a safety line attached. At all times, engine thrust alone provides the lifting and maneuvering forces. As of October 2nd, nine tether flights had been accomplished. The need for some minor control arm rework and changes in instrumentation resulted in removal of the system from flight status for several days. During ground operation after resumption of the test program, several engine "hot" starts were experienced. The engine was returned to Williams Research for inspection and found to be in excellent condition throughout. The primary source of trouble was in the spark plug which was subsequently modified to further penetrate into the burner area. The engine starting technique was modified slightly and coupled with the spark plug rework, eliminated further tendency toward "hot" starts.

(C) Thrust and specific fuel consumption data measured during the acceptance testing (witnessed by Bell and independently verified) after the inspection disassembly and rebuild, are included in Progress Report No. 34 dated November 15th, 1968 and are compared to data from prior engine builds. It is worthy of mention that the measured thrust (corrected to sea level standard) with the bifurcated duct installed, is now 405 lbs. at the governor speed setting. Thrust is now higher than for the earlier build, data for which are contained on the previous page. For a straight tail pipe, the present thrust would be approximately 450 lbs.

(C) In the meantime, a larger facility at Andrews Air Force Base was made available for the remaining tether tests. Two flights were made at Bell prior to departing for Andrews. The last flight was made with full fuel tanks at a take off weight of 350 lbs. Five flights were made at Andrews and completed the tether test portion of the

(C) program. Thus a total of 17 tether flights were necessary to achieve all objectives whereas initially it was estimated that 38 flights would be required. Total engine time to date on the flight engine is 13 hours of which approximately 1 hour has been since the last complete inspection. The engine No. 3 is currently in storage at Bell awaiting the free flight program.

(C) Take-off and landing (at ambient temperatures from approximately 50°F to 75°F), translations in forward and backward pitch and lateral directions, coordinated turns and precise hovering have been repetitively accomplished. The operator reports indicate excellent control, good throttle response, and no adverse human factor effects for the duration of the flights, some of which have been from 7 to 9 minutes. The effect of recirculation (ingestion of hot exhaust gases) which is expected to be most adverse under conditions of tether flight in a confined facility, has been noticeable. The operator reports the effect decreases significantly at three feet above the ground and disappears at 6 to 8 feet. The engine has performed admirably in the testing to date. Starts have been very smooth as has acceleration. Even with the extended engine start procedure currently employed, using the ground start cart (compressed air in lieu of cartridge system), operator mounting the belt, engine start, disconnect from the cart, and take-off have been consistently accomplished in less than two minutes.

(U) Engine #4 (PFRT) was assembled in preparation for the PFRT and "green" run with the deteriorated used 4th/stage stator/diffuser assembly late in the month. (June progress report has duscussion). Improper lubrication and abnormal coast down prompted disassembly for inspection. The main oil feeder line was found clogged and was opened.

It was also found that the radial compressor had picked up flame spray (abrative seal) material from the housing and the resultant heat generated had pitted and scored the remaining flame spray. The part was re-flame sprayed and made ready for reinstallation in the engine. A new 4th/stage stator/diffuser assembly is being fabricated as a spare in the USAF program. Since Engine No. 4 is now slated for delivery to the USAF after test, and since the probability of a successful PFRT increases with substitution of this new part for the deteriorated part, in the best interests of the overall program, reassembly of the PFRT engine was delayed for the new part expected on November 9th. The fuel controller had been returned to CECO for readjustment and repair of a damaged fuel bleed port thread and was expected to be available on November 6th.

New This Month

The PFRT delay was not pacing the free flight program at that time. In recognition of safety, Bell Aerosystems is providing an emergency recovery system to recover the operator in the event of engine malfunction in flight. This system was not scheduled to be available until approximately December 6th. As of this writing, the PFRT is the program pacer.

The PFRT engine was reassembled complete with the fuel control and the new initial runs accomplished on 16 November. During the period through early December several attempts were made to accomplish the pre-PFRT engine runs all resulting in malfunctions. The fuel control has not been performing properly and a significant engine problem in the #4/#5 bearing area was encountered. Both will be discussed briefly here and more detailed write ups are contained in a later section of this report.

The fuel control problem results from a leaking high pressure relief valve which limits fuel flow to less than that required to operate the engine at governor speed. The H.P. relief valve is a new design to correct a weak configuration as originally used. In principal, the new design is more reliable, however, problems were encountered in obtaining proper spring forces and valve seating to provide the desired no leak pressure setting. Too high a setting could result in excessively high engine speeds if the governor should malfunction and too low a setting results in premature cracking with the resultant limitation in fuel flow below that required. Several attempts were made to correct the problem by use of shims to increase the spring force but the limited space resulted in almost bottoming of the spring. As of this writing, the problem has been corrected properly by reworking the valve poppet to accomodate a correct spring with proper constants. The fuel controller has been reset to all parameters obtained from prior No. 4 engine runs and should operate the engine satisfactorily.

A minor fire in the #4/#5 bearing sump occurred during the engine run late in November. This problem resulted in extensive damage to the 2nd stage nozzle assembly, both bearings and the 1st labyrinth seal and drive coupling. The specific cause has not been pinpointed although several hypothesis have been proposed and are being investigated. The 2nd stage nozzle assembly and labyrinth seal from engine No. 2 and new bearings have been installed. A thorough inspection of all engine parts has been made and the engine reassembled for a check run. On the check run made in mid-December, higher than normal vibration attributed to L.P. spool vibration was encountered and the L.P. spool is being rebalanced. Disassembly and inspection of the #4/#5 bearing area revealed no indications of the prior problem.

Progress on the parawing emergency recovery system has been very good with the static ground firings successfully completed by 13 December. The delay was due to late delivery of the drogue deployment gun from the vendor. Static ground firings of the complete system demonstrated the capability to deploy the parawing to full riser length. The Jet Belt has been modified to accommodate the recovery package and the harness system modified to separate the Jet Belt from the operator with deployment of the recovery system.

Due to the difficulties encountered with the engine during November and early December, the estimated date for completion of the PFRT is now by the end of December if no further problems are encountered. If this PFRT schedule can be held, free flights will occur early in January. The engine problems and associated delays may result in a requirement for additional funds. Informal discussions have been held with the ARPA, AVSCOM and USAF program monitors.

INTRODUCTION

(U) In April 1964, Bell Aerosystems Company and Williams Research Corporation submitted a joint unsolicited proposal to the U. S. Army Mobility Command and subsequently to ARPA for design, fabrication and test of an Individual Lift Device known as the Jet Flying Belt. As a result of this proposal a prime contract was awarded to Bell Aerosystems Company on 30 December 1965. The program is being funded by ARPA and administered and directed by the U. S. Army AVCOM in St. Louis. Williams Research Corporation was subsequently selected by Bell as a major subcontractor to develop the power plant.

(U) The Jet Flying Belt utilizes essentially the same general configuration and control concept successfully proven on the Bell Rocket Belt which has accumulated over 3000 flights to date. The Jet Belt is powered by the WR-19 bypass fan engine being developed by Williams Research for this application. This propulsion system significantly improves endurance, range and utility over the rocket powered system.

(C) The purpose of the Individual Lift Device or Jet Flying Belt is to provide a substantial improvement in individual soldier mobility for a variety of select mission applications such as (1) observation (2) reconnaissance (3) forward observation and liaison (4) overcoming natural and man made obstacles (5) clandestine operations and (6) delivery of personnel and parts for in-place maintenance.

(C) The basic objective of the present contract is to develop a flight demonstration model to demonstrate feasibility of the system, and ranges up to 10 miles and a speed of 60 mph. One flying belt,

(C) a spare engine, residual hardware and data are deliverable items, under the contract.

(U) Bell, as Prime Contractor, is responsible for overall system management, system integration, design, fabrication, and flight test. Williams, as a subcontractor, will design, fabricate and test the engine. Olin Mathieson has been selected to develop a solid propellant cartridge for use in the Jet Belt self contained start system.

INDIVIDUAL LIFT DEVICE - PHASE III

TETHER AND FREE FLIGHT TEST PROGRAM

General

During the reporting month the effort at Bell Aerosystems was primarily concerned with rework of the Jet Belt to provide the capability for separating the system from the operation during emergency recovery. Other minor tasks involved preparations for free flight.

Fabrication of the emergency recovery system at Irvin Industries proceeded on schedule. Static ground tests were conducted at Irvin Industries and preparations are in progress for the static air drop tests to be conducted at Fort Benning in mid December.

Williams Research continued in their efforts to initiate the informal PFRT on engine No. 4. Difficulties encountered in running the engine with fuel controller No. 3 and a mechanical failure in the area of the No. 4 bearing resulted in further postponement.

Instrumentation

During the tether tests concluded late in October, certain operations indicated the need for minor modifications to the Jet Belt system; particularily, in electrical circuitry of the two-way communication, telemetry, and operator warning subsystems. These were achieved during the past month.

The technique used for making the electrical connections between the operator's two-way communications and warning system was found to be time consuming and cumbersome and appeared to be of rather low reliability. Simple re-routing of the wiring, replacement of the connectors, and, in some instances combining more than one system circuitry in a single disconnect provided an electrical system which appears significantly more reliable and much more amenable to overall flight preparation thereby enhancing the free flight program and flight safety.

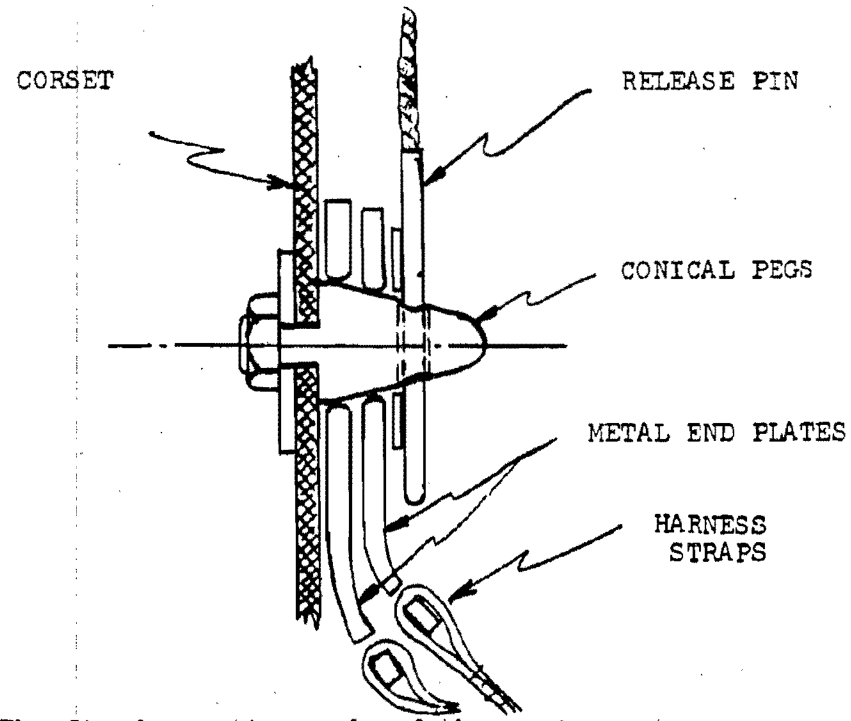
An intermittent short in the operator warning system encountered during later tether flights was traced to a weakness in the low level fuel warning arrangement. This was repaired in a manner which precludes further occurrances.

Some of the connectors within the electrical subsystems proved troublesome at times and some appeared questionable after review. Necessary replacements or modifications have been incorporated to the extent that the overall system is now significantly more flight worthy.

A periodic check between the accelerometer (vibration) readout from the airborne telemetry system and that from the equipment employed by Williams Research (and hardlined during some of the tether flights) indicated some discrepancies. The press of time prevented this situation from being completely remedied during the course of the tether tests. During the past month a careful review of the two systems was accomplished. The causes of their differences were found to be in the response of the accelerometer pickups and in the electronic circuitry delivering the signal to the readout instrumentation. A modification to the miniaturized electronic circuitry of the airborne telemetry was incorporated and checkout shows that the output from the two pickups and associated circuitry now correlate very closely.

Operator/Jet Belt Emergency Recovery System

Preparation for installation of the emergency recovery system, defined and designed to recover the operator only, necessitated changes in the Jet Belt suspension system to provide separation between the operator and the Jet Belt. These changes pertain primarily to the attachment points of operator suspension harness on the Jet Belt i.e. groin, abdominal, and shoulder straps. The previous harness attachment bolts were replaced by chrome-plated, conically shaped, steel pegs with a hole near the apex for the attachment and release pins. (see Sketch "A")



The fixed mounting ends of the various straps were provided with metal plates which have holes drilled to fit loosely over the conical pegs. Placing the appropriate attachment plates over the proper conical pegs and inserting the release pins through the holes near the apex of the pegs as shown in the sketch results in a suspension system configuration exactly the same as the previous permanently attached harness.

With the straps in tension, as they are when the Jet Belt is being worn, removal of the release pins allows the load on the straps to pull the end attachments free. As a result, the flexible corset, with the rest of the Jet Belt, is loose and free to fall away from the operator under its own weight.

In conjunction with the emergency recovery system, the release pins are connected to the Parawing risers by means of protected flexible cables in a straight line of forces to remove the pins cleanly to prevent binding. Thus, the opening forces of the parawing pull the pins which release the operator from the Jet Belt permitting the deceleration forces on the operator to pull him free of the Jet Belt.

Static Separation Ground Tests

During the past month, this system was fabricated and installed on the Jet Belt Mockup. A series of static ground tests were conducted to ascertain the separation characteristics. These were performed by attaching the mockup to an overhead chain hoist by means of a slack cable of short enough length to prevent the mockup from hitting the floor. The mockup was donned by the operator who stood below the overhead hoist. The cables to the release pins were pulled from above in the same manner in which they will be pulled by the risers, by means of the opening shock of the Parawing. A dozen such separations were performed to prove the repeatability of separation. The operator expressed complete satisfaction with the system and said that he felt nothing other than the release of the straps' tension and the falling away of the corset.

During these tests, the force required to pull the release pin was measured. While there was some small variation from test to test the nominal pull force was about twenty pounds for each pin. This force is small relative to the Parawing opening shock which will be in excess of 300 lbs.

This recovery system approach necessitates the use of an additional harness for operator suspension from the parawing. For this purpose an available lightweight nylon garment with an integral harness has been used. The garment has been modified to reduce its weight and tailored to fit the operator. The operator, wearing the suit, has been suspended off the ground for as long as fifteen minutes with no discomfort or effect on circulation to the legs or arms.

Emergency Recovery System

As reported last month, Bell Aerosystems has supported the Jet Belt Program by funding Irvin Industries to design, develop and test an emergency recovery system for the Jet Belt operator. Work at Irvin proceeded ahead of schedule, but a last minute delay in the delivery of the deployment mortar gun forced a one week postponement in the initiation of static ground tests.

The first test was conducted on Thursday, December 5th. Full extension was not achieved and was attributed to the fact that the mortar slug was lighter than specified. A second firing with a heavier slug was made in which further extension occurred, but the parawing still did not fully deploy. After viewing the high speed motion pictures, it was concluded that the method of packing had to be revised to provide a progressive increase in the amount of mass beir removed from the canister.

A third firing on December 10th succeeded in full deployment of the parawing and all but the last two folds in the shroud lines extended. Minor revisions in the tying and packing procedures improved conditions to extent that after the sixth test on Thursday, December 12th, it was decided that the system was ready for the static air drop tests from the drop towers at Fort Benning, Georgia. The schedule now calls for the first air drop to take place on Monday, December 16th.

The complete system weight is 11.43 lbs. This, with the integral harness-garment weight of 2.75 lbs. brings the total weight of the emergency recovery system to 14.2 lbs.

Fuel Tanks

Two factors have been revealed during the time period of the flight system operation. The first is in regard to fuel slosh which occurs when the operator makes small, rapid control inputs (especially in pitch). This type of control input occurs more frequently in tethered flight where operating distance is severely limited. The second concerns the noticeable "crazing" present in the polycarbonate fuel tank walls. This crazing has occurred since the tanks were put into service.

Tank Anti-Slosh System

The slosh, evidenced during the tethered flights did not result in a problem but is considered sufficient to warrant the installation of an anti-slosh device which would preclude unporting of the fuel tank outlets during maneuvers. During free flights, without the maneuver limiting safety line attached, and with less specific control of fuel remaining at touchdown, this could become a problem. Normally, it is a rather easy matter to install baffles. In this case a solution proved quite difficult because the only access, without cutting holes in the tanks, is through the fill port and the hole for the actuator of the low level fuel warning system. Several approaches were considered; including, plates, screens, perforated ping-pong balls, and Firestone "reticulated" polyurethane foam, a sponge-like plastic especially made for this purpose.

Conventional baffle plates and screens were impossible to install and perforated ping pong balls used too much volume and resulted in a higher possible trapped or unusable fuel. A test tank was partially filled with Firestone foam. When filled with fuel, air bubbles appeared to adhere to the sponge like plastic. Shaking the tanks failed to dislodge the bubbles but the condition gave concern that the bubbles could come free in flight and possibly enter the fuel controller. Tests of fuel flow from the tank were made and the sponge material did not impede the exit fuel flow nor did the bubbles flow with the fuel. However, the presence of the air bubbles gave sufficient concern to abandon this idea.

The approach finally selected consists of a short piece of large diameter polycarbonate tubing with flow area holes around the circumferance at the bottom. The tube is attached to the tank fuel outlet fitting where it protrudes into the bottom of the tank. (It should be noted that the movement of the center of gravity due to slosh had no effect on control or flight stability and the objective is to prevent unporting of the fuel tank outlet). This device was made and mounted in an unusable fuel tank for the purpose of test. Several tests were performed during which the flow rate out of the tank was regulated to be slightly in excess of the maximum engine fuel flow requirement. During the tests, fuel was allowed to flow until the first air bubbles appeared in the transparent line leading from the tank outlet (near empty tanks). At this point flow was stopped and fuel level in the tank recorded. Tests were performed with and without the slosh baffle in place and with the tank held steady as well as rocking to simulate slosh. It became evident that the minimum permissable level of fuel occurs when the vortex forms in the fuel at the tank outlet during tests with the tank held steady. With the slosh baffle in place, this same minimum fuel level was attained while rocking the tank to simulate slosh. When rocking the tank without the slosh baffle, the minimum level of fuel in the tank was appreciably higher, when air bubbles first appeared in the outlow line.

This type of baffle has now been installed in the flight tanks. In addition, the float for the low-level fuel warning system will be adjusted to provide a larger fuel reserve above the minimum fuel level.

Fuel Tank Crazing, AND

The crazing present in the fuel tank walls has been noticed for some time and has progressively increased. In some of the tanks which have not been used, small areas of crazing have also been found. It appears that, during the process of rotational molding, inherent stress areas are formed which make themselves evident after time and use by crazing. It also appears that exposure to JP-4 has an effect on the extent to which the crazing occurs. The tanks in use to date have been periodically checked to ascertain their strength characteristics. Even with a locally concentrated applied load no evidence of a reduction in structural integrity has been ascertained. A sample of polycarbonate, under stress by bending, has been immersed in JP-4 since 1965. Crazing has occurred in this sample. It has been strength tested and the reduction in strength due to crazing seems to be minimal.

As a precautionary measure, a set of new tanks have been prepared for use during the forthcoming free flights. These show some small areas of crazing, but considerably less than the tanks presently on the Jet Belt.

Free Flight Plans AND

Although initiation of Jet Belt free flight testing is dependent on the completion of the 50 hour PFRT, a detailed plan for these flights is being prepared. The plan calls for reassembly and checkout of the Jet Belt and its subsystems followed by one or two static ground tests with the Jet Belt mounted on start cart. In order to sharpen up the operator, two tethered flights will be performed in the flight hangar at Bell Aerosystems. Then, several "low and slow" free flights will be conducted over land. If weather permits, these flights will be performed on the Niagara Falls Municipal Airport; otherwise they will be conducted at the former Air Force base located near Bartow, Florida. Arrangements have been made for the use of this facility for the majority of the free flight program.

Detailed flight plans are being prepared for each of the envisioned flights and are being designed to obtain the maximum information with the least number of flights. The last flight will be for the purpose of contractual demonstration of range and speed objectives.

The initial "low and slow" flights refer to low altitude (just above that at which exhaust gas recirculation causes a rise in inlet air temperature) and speeds not in excess of 15 miles per hour. These flights will give the operator the "feel for" the system in free flight in a flight regime which is not catastrophic in event of system malfunction or operator error. Subsequent flight profiles will be designed to conduct tests within the safe recovery area of the parawing system or if intermediate altitude and speed testing is required, it will be accomplished over water.

ENGINE PROGRAM - PHASE II

WR-19 Engine Model Specification

The final draft of the Model Specification for the WR-19 Engine was received from Williams Research. It has been reviewed and accepted by Bell Engineering personnel and will be submitted to AVSCOM in the near future. This specification defines the flight engine and the PFRT engine.

PFRT - (Engine #4)

Upon availability of the new 4th stage stator diffuser assembly, the engine was reassembled and the new break-in run accomplished on 14 November. The test cell lubrication and fuel system were used as is normal for the initial run. Engine operation appeared correct throughout the run. Disassembly (usual practice after a seal break-in run) and subsequent inspection revealed everything normal except for some coking of oil in the #4/#5 bearing cavity. The bearings and surrounding structure were not discolored. All parts were inspected; bearings were cleaned; and the engine was reassembled. A specific cause for the coking was not found. The condition was attributed to lower than normal oil flow to the #4/#5 bearing cavity as a result of seal leakage and higher than normal cavity pressures.

The complete engine (self contained lubrication and fuel control) was run on 16 and 17 November to verify performance prior to initiation of PFRT. The start schedules, acceleration schedule and governor limited fuel flow were unacceptably low. Engine speed was limited to 52,700 RPM, which came as a surprise, because the governor in this controller was removed from S/N 102 controller and S/N 102 had operated engine No. 3 at 53,750 RPM during a test run several months ago. This condition stimulated the concept that the high pressure relief valve was cracking too soon or leaking and was limiting fuel flow at the high speed end. Adjusting the unit at Williams improved the performance to some extent, however, the controller suddenly ceased to deliver fuel. On 17 November it was returned to Chandler Evans for investigation and repair. It was found that a small brass chip (origin undetermined except that it was probably from machining of the fuel pump face plates) had become lodged under the metering head valve seat. This permitted all fuel to bypass the fuel pump and prevented delivery of fuel. The high pressure relief valve was lapped into the seat to assure a proper seal. Fuel controller S/N 103 was returned to Williams on 25 November.

During the interim period, engine inspection indicated no coking effect in the #4/#5 bearing cavity. Engine vibration had been higher than desired and required a rebalance of the axial compressor.

Engine runs on November 26th and 27th again disclosed insufficient engine speed. The fuel control was instrumented to obtain internal fuel control pressures and fuel delivery rates at select data points to better understand the reasons why the controller would not run the engine after having successfully passed the calibration run on the test stand. These test results conclusively proved the high pressure relief valve was performing improperly and along with the specific engine parameters were sent to CECO with the controller. This situation is covered in more detail in the subsequent section of this report.

Late on Wednesday, November 27th, while the engine was running at ground idle, an unusual hum was heard emanating from the engine and high vibration was indicated. The engine was immediately shut down, removed from the test cell, and disassembled. Inspection revealed that the No. 4 bearing cage had disintegrated, allowing the rollers to run together. The outer race had broken into several pieces and had been slung out against the inner wall of bearing carrier.

Another failure occurred at the rear of the high pressure spool labyrinth seal coupling. The portion of the seal cylinder containing the aft three labyrinth seal lands had broken into several pieces and had been slung radially outward. These bits of steel pierced the outer wall of the oil cavity and were caught in the area bounded by the conical bulkhead and the upstream heat shield of the second stage nozzle assembly. Oil was slung into the same area through the holes torn in the oil cavity wall.

There was conclusive evidence that a fire had occurred in the oil cavity as well as in the area surrounding it. The fire was apparently hot enough to melt the braze in the joint where the air balance line entered the oil cavity wall, since the braze material was gone. Metallurgical examination indicates evidence on the surface of the two parts that braze had been there. Williams Research is presently conducting an investigation to ascertain the sequence of events leading to the failure and evaluate the several hypotheses on possible failure causes. Results will be reported in next month's progress report.

Meanwhile replacement parts have been salvaged from engine No. 2. They have been thoroughly inspected and found to be in good condition.

After exhaustive discussion and review failed to reveal a specific cause for the failure, it was decided to reassemble the engine with the replacement parts from engine No.2 and new bearings and conduct investigative runs. The possibility of getting fuel into the bearing cavity through the CDP pressurization line was tested and discounted. A short build verification run was made under careful scrutiny. Nothing unusual was encountered during the run except that vibration was again high and a rebalance of rotating machinery is being made. Inspection of the #4/#5 bearing area and all parts relative to the previous failure indicates everything appears normal. This later run occurred at mid-December.

Fuel Control

Fuel Control S/N 103 which has been designated for the PFRT on engine #4 has been highly erratic in operation thus far. The problems encountered have been different from those experienced with S/N 101 control during acceptance test of the flight engine. Problems with S/N 103 controller stem both from physical changes made in the fuel controller as well as the incorporation of improperly specified Fuel Controller Performance parameters, the latter being the greatest contributor.

High Pressure Relief Valve

A physical change in the high pressure relief valve configuration was incorporated to increase reliability of a suspected low reliability design. This valve prevents excessive pressure from occurring within the case of the fuel controller, and is particularly important in limiting maximum fuel flow (hence engine RPM) in the event of a governor failure. It also functions as the fuel flow shut off valve when over ridden by closing the throttle. The original design of this valve, which has been trouble free to date, consisted of a flat valve seat and a flat poppet faced with a hard plastic sealing surface (Roulon). The limiting diameters of the orifice (for proper fuel bypass) and valve cavity because of overall controller size limitation resulted in very little overlap of the valve face on the seat. The potential problem of the Roulon extruding or taking a set (similar to the problem experienced with the fuel pump face plates of the same material) and the possibility of the Roulon chipping or cracking because of the small overlap prompted the redesign. Either of these conditions would result in leakage across the valve to the inlet side of the pump thereby reducing fuel flow to the engine. This has in fact been the problem with the redesigned valve.

In principle and in fact the new configuration valve is inherently more reliable. The major concern has been the advisability of undertaking the change (irreversible) at this time. Considering the potential valve failure and the new configuration being straight forward, CECO and Williams Research went ahead with the change.

The new configuration valve consists of a chamfered valve seat and a conical valve shape. The valve or poppet sealing material was changed to a softer synthetic rubber compound shaped to fit the chamfered seat to assure better sealing. In operation this valve has been cracking prematurely and has limited fuel flow to less than that necessary to achieve engine operation at governor speed. One of the primary reasons lies in improper relief pressure setting incorporated.

It was determined that the back pressure imposed by the engine on the fuel delivered by the controller was some 30 psi higher than has been specified to CECO as the set point for the controller. Attempts to shim up the spring to increase the force on the valve (hence fuel relief pressure) resulted in near bottoming of the spring. At the expense of additional delay of several days, this condition has been properly fixed by boring the spring seat deeper in the poppet, and incorporating a stiffer spring. It is believed that the relief valve problem has been resolved.

Adjustment and Calibration

The other problems (continual throughout the program) have their roots in fuel control adjustment and calibration thought to be resolved several months ago. It has been highly disconcerting that the fuel control could be set at CECO to specified parameters and upon arrival at Williams Research would not run on engine properly. Starting fuel flows and acceleration/deceleration flows always require adjustment on the engine. This has been a major problem with S/N 103 controller on the PFRT engine during the last month and resulted in a detailed investigation.

Williams Research had supplied Chandler Evans with the estimated Engine Performance parameters required to adjust and calibrate the fuel control unit and some of these have never been corrected from original design data. In essence, these consist of the variation of the compressor discharge pressure and fuel flow with speed; governor limit speed (vs fuel flow); maximum back pressure against which fuel must be delivered, and a specified level of fuel flows during start. A review of the parameters and a comparison with the actual engine characteristics and requirements revealed some discrepancies. Examples are (1) the actual maximum back pressure against which fuel must be delivered is 30 psi higher than that specified and as noted previously this is a major contribution to the high pressure relief valve problem and (2) the compressor discharge pressure bias was not established, resulting in an unknown bottoming pressure on the fuel metering valve. The problem with the later condition is that with a high CDP bias, the metering valve doesn't come off the minimum flow stop after ignition (start fuel flows) which results in engine hang up at speeds below idle, as experienced on a number of occasions.

Specific data obtained from the several runs of engine No. 4 (PFRT) have been transmitted to CECO and the S/N 103 controller is being set accordingly. Among other parameters, the S/N 103 Controller fuel flow setting now should be adequate to obtain an engine RPM of approximately 53,700 RPM which is the governor setting. This RPM is required to assure engine thrust levels will satisfy the specification.

CONTRACTUAL STATUS

GENERAL

The highly elusive PFRT initiation milestone has not been achieved and has forced delay of the free flight program at least into January. As a result of the problems encountered in Engine No. 4 thus far, additional funds may be required. Informal discussions have been held with the project monitors at ARPA, AVSCOM and WPAFB concerning the overall situation. The problem is being reviewed and information will be forthcoming in the near future.

PROGRAM PLAN

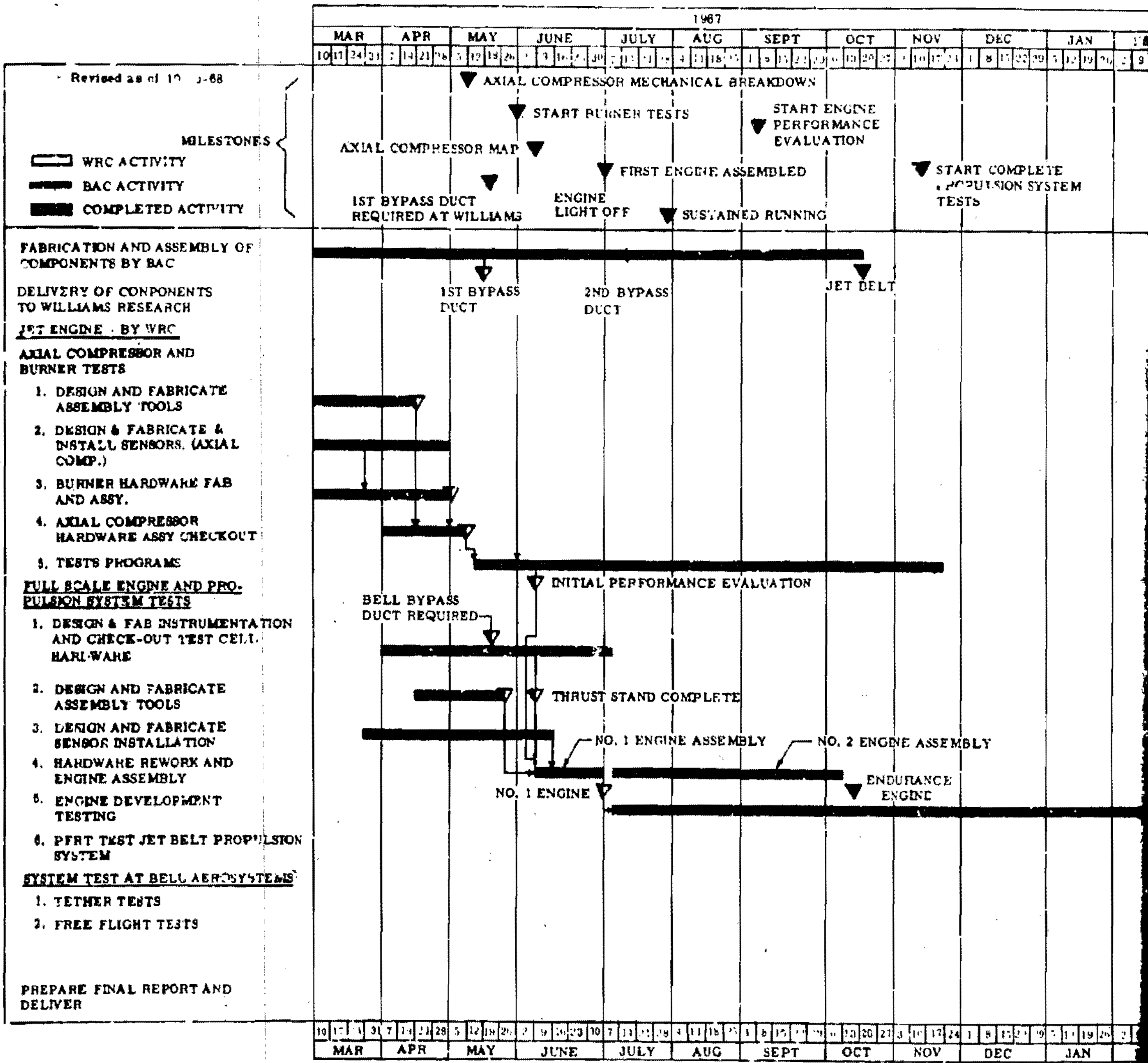
Difficulties encountered in the engine have prevented initiation of PFRT; hence, have delayed the free flight program and anticipated contract completion during December, noted in the last monthly progress report. Schedule progress is entirely dependent on completion of PFRT, the initiation of which is now delayed at least until December 20th. As a result of the single milestone dependency, the program plan has not been updated.

The recovery subsystem is progressing with the static deployment tests successfully completed on December 12th and the two drop tests scheduled at Ft. Benning on December 16th and 17th. Delays were encountered in delivery of the parawing deployment drogue gun. The Jet Belt modification has been completed to accomodate the recovery subsystem.

It now appears that the free flight program will be delayed until early in January. Plans have been made to accomplish the free flight program at Bartow, Florida to prevent further delays because of the severe winter weather at the Bell facility, normal for the next several months.

BELL A

INDIVIDUAL LIFT DEVICE PROGRAM PLAN *
PHASE II AND III



*NO REVISION TO PROGRAM PLAN THIS REPORTING PERIOD

Report No. 2203-953035

BELL AEROSYSTEMS COMPANY

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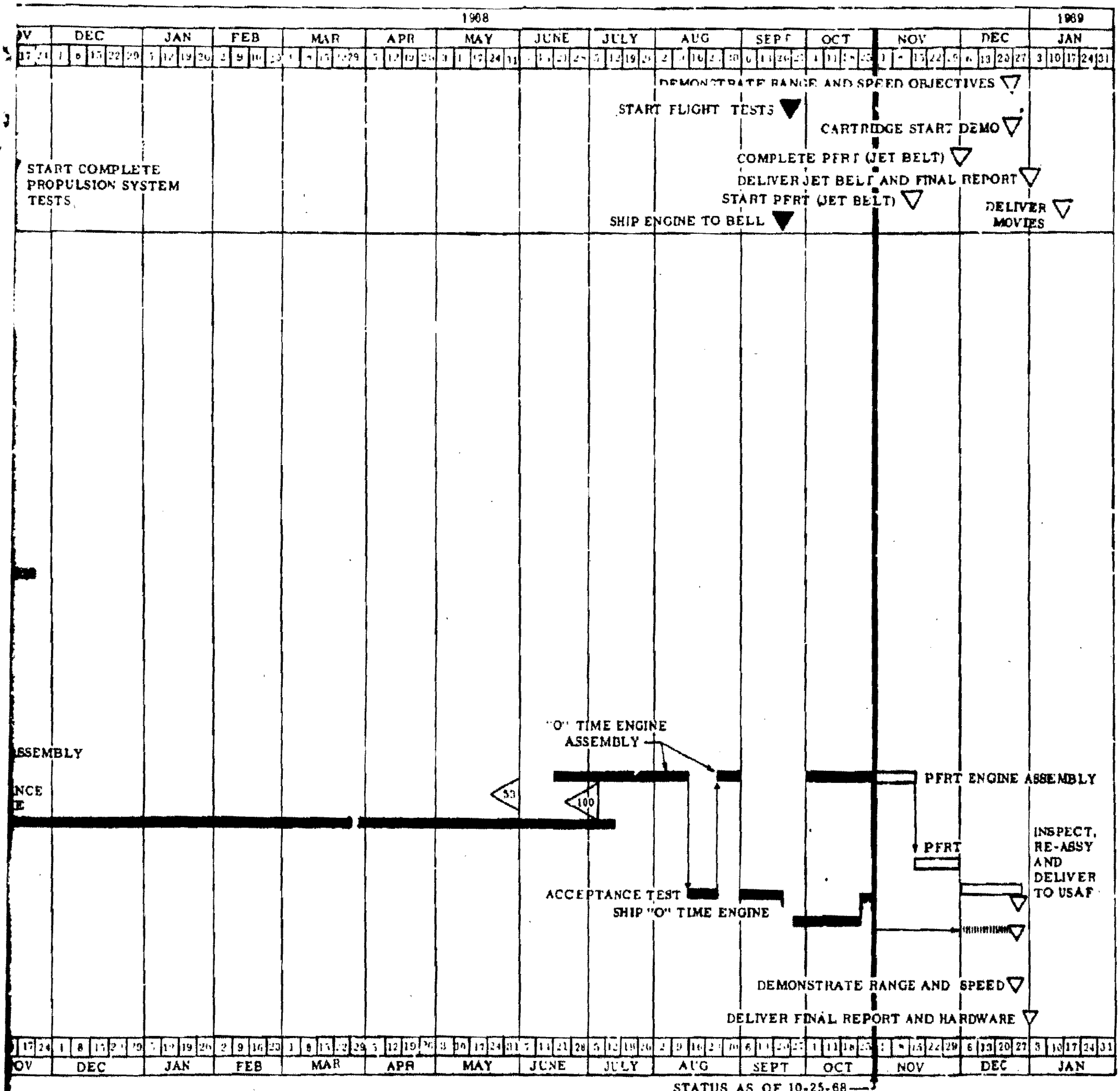

FISCAL

The following table contains a fiscal summary for the basic Jet Belt Program as of November 22, 1968 which is the end of the last accounting period.

Total Funds Available		$3,021,700
BAC Expenditures	$920,800	
Engine Subcontract (Liability)	$2,055,000	
		$2,975,800
Remaining Funds (11/22/68)		$ 45,900

Costs associated with development, fabrication and testing of the parawing and associated costs for Jet Belt modification and recovery system installation are being funded by Bell Aerosystems. Irvin Industries, the parawing subcontractor, is partially supporting parawing development.

VISITS

The following visits were made in support of the program during the past month.

(1)	Williams Research	Walled Lake, Michigan	Witness PFRT engine calibration runs

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