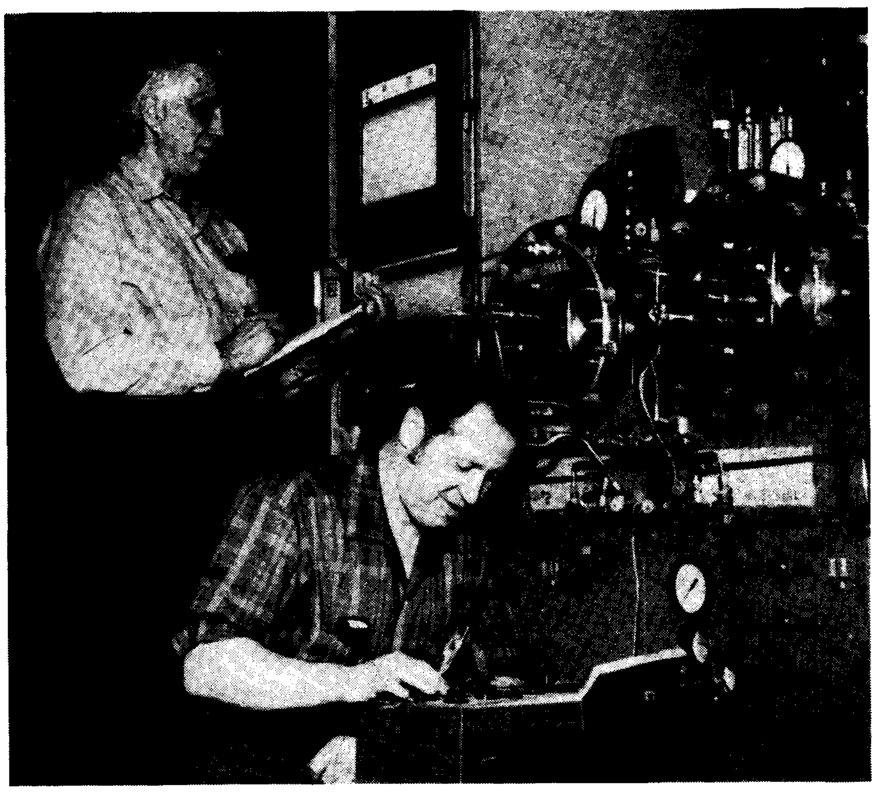
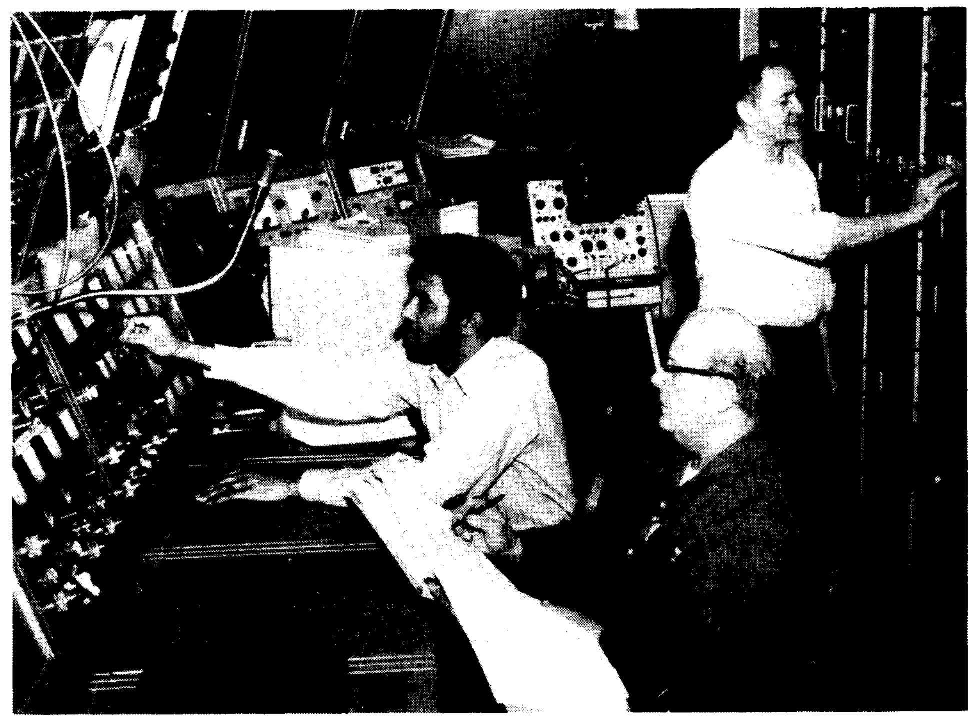


Howard Schultheis (standing) and Bill Funk take readings on furnace for processing metal powders.



Harold Gustin (foreground), Vern Mays and Steve Palko monitor test from Dynamitron Control Console room.

Skilled tradesmen

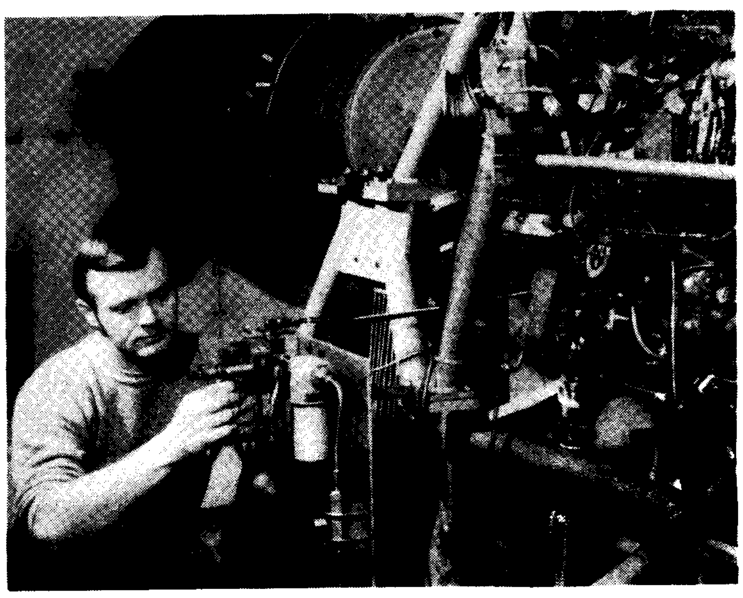
Personnel in the Materials and Rockets Branch, the largest at Lewis in terms of manpower, are proud of their technical support to some seven research divitions ranging from rocket engine testing to processing sub-micron powder used for producing new materials.

Headed by George Tunder, the 145 aerospace mechanics, electricians, electronic mechanics, electrical equipment operators, and apprentices set up, operate, and maintain research equipment in more than 10 areas around the Lab. Three section heads: Louis Herman, William Lang and Joseph Kulik supported by nine supervisors oversee the branch's activities.

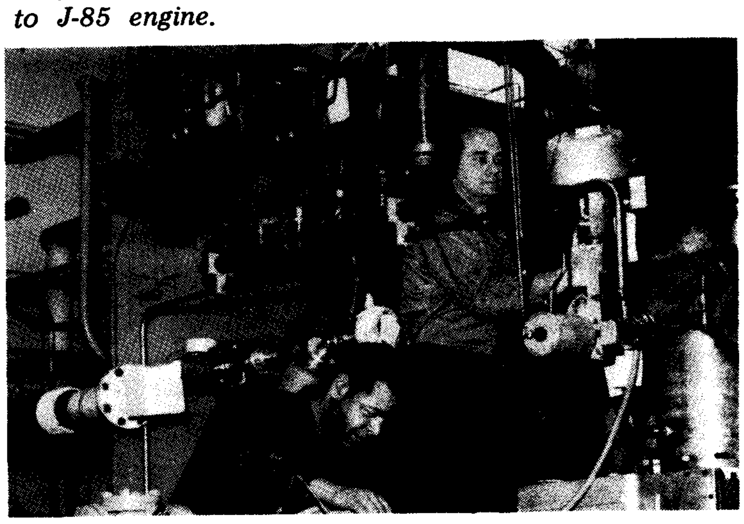
About 45 percent of the Branch's personnel is assigned to the Materials and Structures Division. There the technicians support engineers involved in studying refractory materials, metals and advanced superalloys. Located in the Materials Processing Laboratory is the branch's toxic machine shop — the only one of its kind within a five-state area. Manned by trained personnel, it is equipped with absolute filter systems, and all radioactive and toxic materials requiring machining are checked regularly by the Health Physics Section.

At the Rocket Engine Test Facility, Tunder's men are converting that facility to test the Research Propulsion Module components.

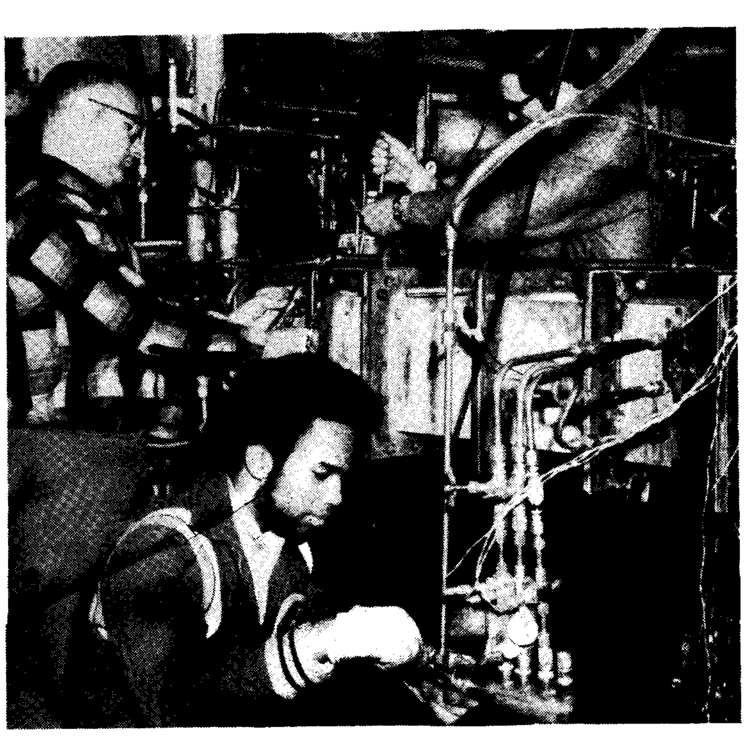
Tunder's men are involved in almost every type of research program at the Lab, providing needed highly skilled technical support. Initials like RCL, HEFL, SPL, ORL, MPL, LMCL, RETF, BML, FML, and M&S are all familiar to these men. They are initials for facilities where much of the Lab's research is being conducted and where the Materials and Rockets Branch plays a very vital support role to bring about the success of the various projects.



Gary Lorenz checks hydraulic fail-safe unit attached to J-85 engine.



Willie Napier (left), and Ed Krawczonek convert environmental chamber in Rocket Engine Test Facility to accept components for rocket propulsion module.

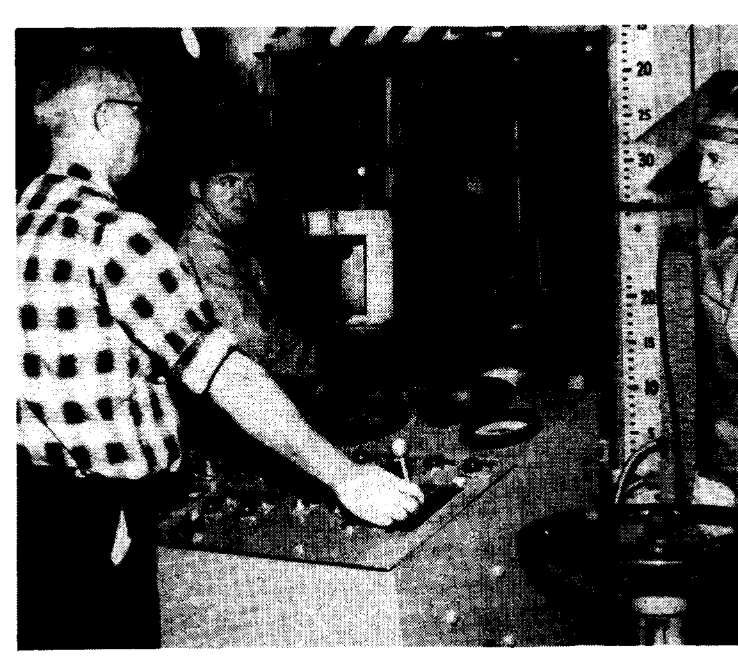


Stan Wilkins (foreground), Bill Lechine and Jerry Ulmer prepare test bed for testing advanced burner configurations in Rocket Lab.

John Dorner (left), Barry Willison and Gene Hunter install vacuum jacketed cover at the high load tensile testing facility in south area.

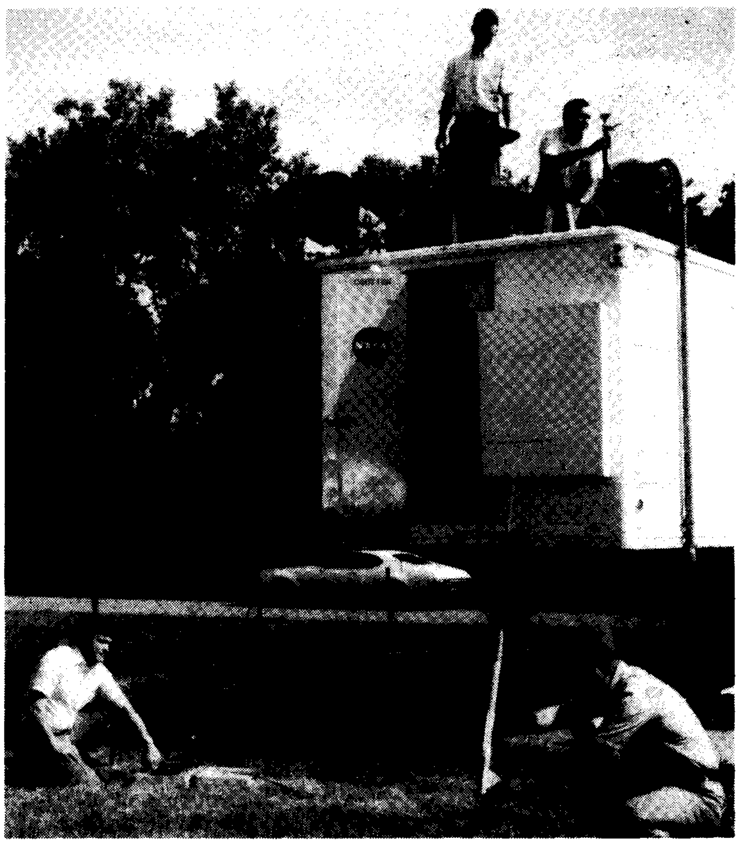
Photos by

John Marton



Al Dolinshek (at controls), Lou Manyak (center) and Bud Tesack prepare to extrude refractory material on a 1000-ton extrusion press.

They solve energy problems; aid Shuttle technology



Jack A. Saltzman (left), Tom A. Coney, Daniel D. Chrulski and Ralph J. Slavik launch sounding rocket in preparation for atmospheric pollutant tests.

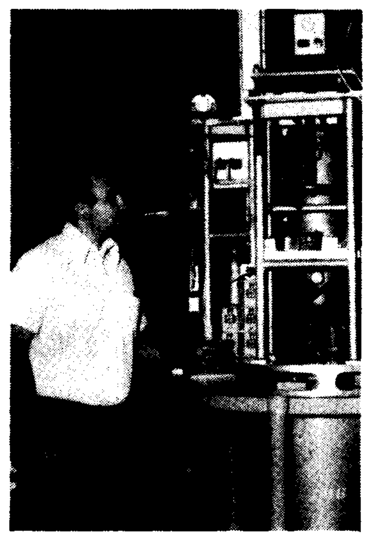
Max Melner (left) and George A. Repas discuss new designs for a combustion program.

Branch Chief Eugene M. Krawczonek (left), Edie J. Donohue and Elias L. Corpas plan scheduling for Zero G Facility.

Neal F. Wingenfeld (left) and Larry C. Leopold prepare to operate low cycle fatigue engine from control room.

Photos by Martin Brown & Don Huebler

Advancement in the exploration of space, depends on the advancement of propulsion and launch vehicle technology. A chemical rocket program at Lewis is aimed at improving performance, reliability, re-useability of rocket engines while at the same time, reducing the development time and cost of tomorrow's rocket engines.



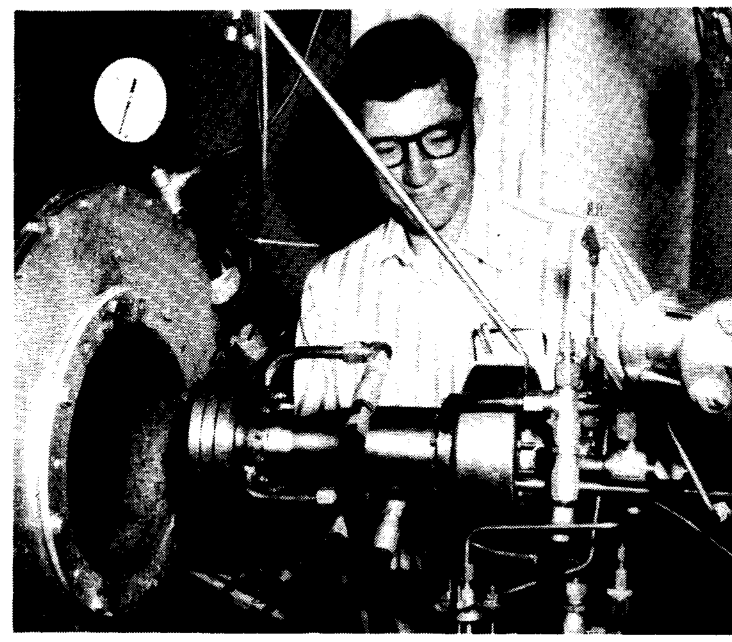
Ray G. Sotos examines new drop vehicle at Zero Gravity Facility..

Handling the operation of facilities for conducting these and other tests are members of the Propulsion Operation Branch headed by Eugene M. Krawczonek.

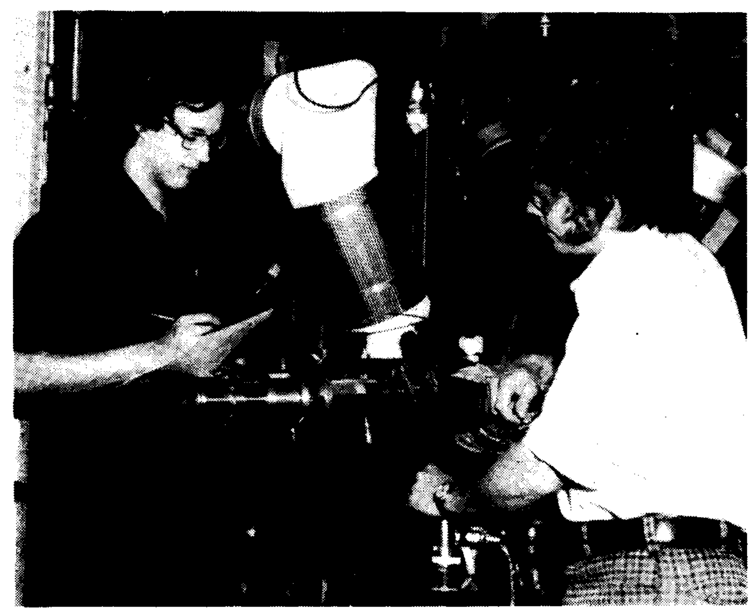
To a farmer, the "south 40" could be the back 40 acres of worthless bottomland, but Lewis' "South 40" houses such impressive facilities as the Rocket Engine Test Facility, the Fracture Mechanics Lab, Calorimeter Test Facility and the Laser Rig. All these facilities are actively running in support of various Lewis programs by members of the Propulsion Operations Branch.

David W. Vincent conducts test on multi-layer insulation blankets.

In addition to the South 40 area, personnel of the branch also handle operations at the Zero Gravity Facility and several cells at the Rocket Lab.



John A. Kobak runs MHD combustor to support energy program for a research division.



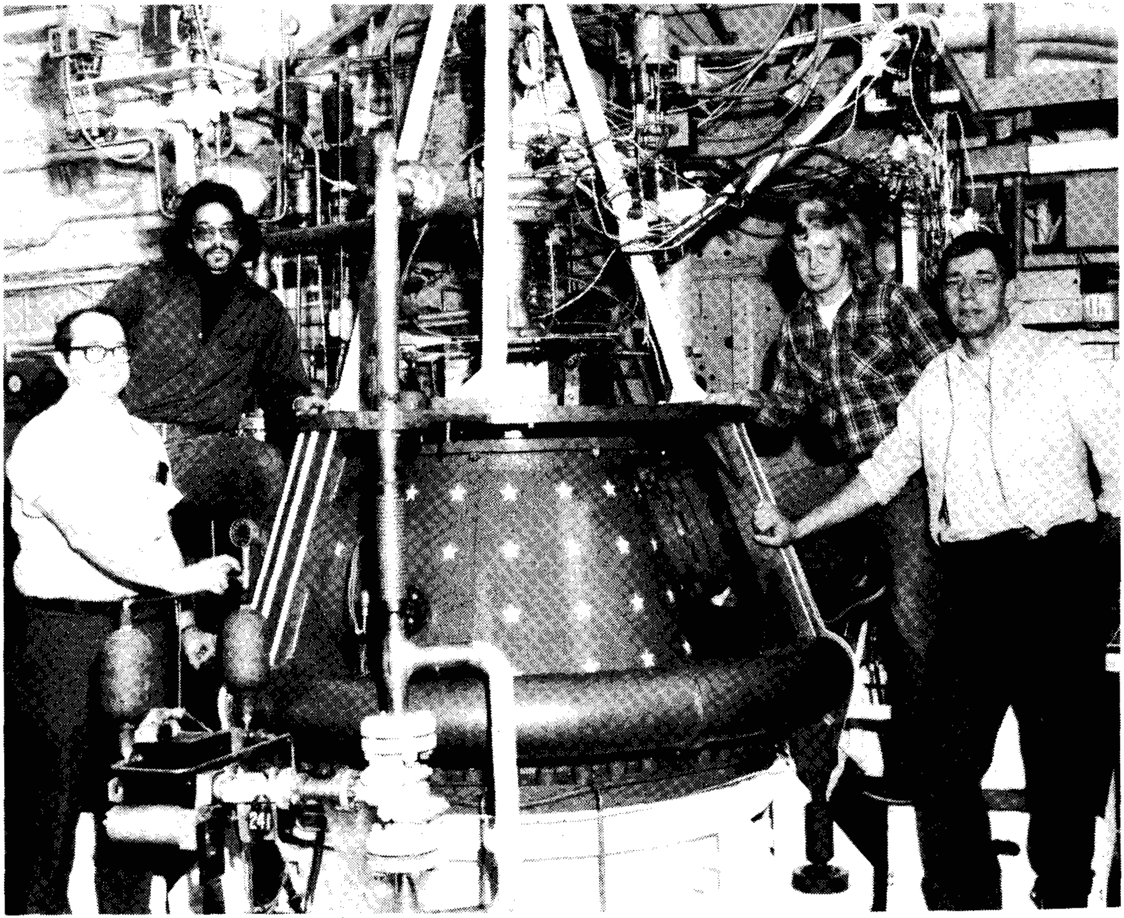
Darold L. Neff (left) and Scott D. Meyer inspect attitude control research rocket facility.

Bernard I. Sather (left) and Wayne A. Thomas make out S-40 facilities schedule.

The Zero G Facility recently completed its 1000th drop and has "demonstrated a remarkable versatility in adapting drop packages to the needs of the various research programs it serves," Krawczonek said. Averaging about one drop per day, the facility is providing continuing support to Centaur, Viking and various other Center projects.

At the Rocket Lab, Krawczonek's men recently completed a Shuttle Attitude Control Rocket program which amassed probably a world record total of 51,000 firings on one engine. Affectionately dubbed the "belching dragon" because of the cycle mode of testing, the contractor-designed engine operated well beyond its normal expected life, according to Krawczonek. "Tests like these provide in-house verification of possible designs for various Shuttle engines and significantly contribute to that overall effort."

From energy problems to Space Shuttle technology, members of the Propulsion Operations Branch are providing their services and expertise to run the facilities.

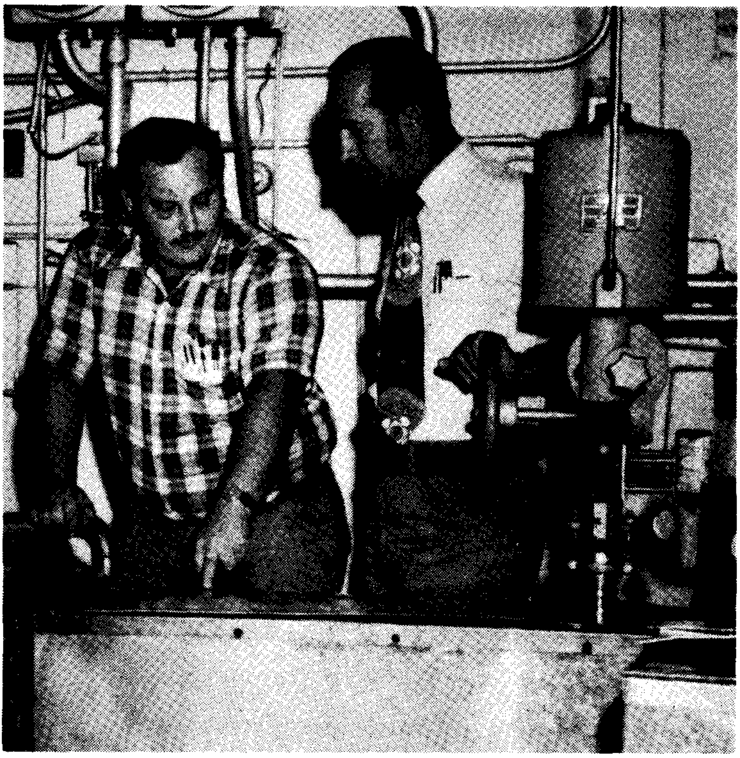


Rocket's red glare

The bicentennial spirit has reached Lewis in a very dramatic way. The crew responsible for operating the Rocket Engine Test Facility in South-40 decided to paint the rocket engine test stand red, white and blue not only to mark the nation's 200th birthday, but also to mark the 20th anniversary of the Rocket Engine Test Facility. The dual celebration idea was the brainchild of (left to right) Edward M. Krawczonek, Wendall White, Kenneth R. Whitney and James P. Gerold. (Martin Brown photo)

NASA
Lewis Research Center
Cleveland, Ohio

September 17, 1976



Howard J. Cobb (left) explains to Test Installations Division Deputy Chief George Tunder his suggestion which keeps the Rocket Engine Test Facility Operating during modification of the facility. (Martin Brown photo)

3 earn monetary award

The Incentive Awards Committee has announced that three more employees have received monetary awards for suggestions.

Howard J. Cobb III of the Test Installations Division was presented a cash award of $250. He suggested removing the Number 2 High Pressure LOX Tank instead of the Number 1 LOX Tank to allow the Rocket Engine Test Facility to continue operating during the six month modification of the facility.

Cobb's suggestion prevented downtime and lost research run time of the rocket engine test facility which is currently testing engines for the important Space Shuttle program.

Lee M. Woods of the Facilities Operations and Maintenance Division and Dennis J. Fischbach of the Test Installations Division divided $182 equally for suggesting a better procedure to operate the 8 x 6 Wind Tunnel drive.

Their suggestion, aimed at saving electrical power, involves installing a low speed rheostat setting to reduce the current program from 760 rpm to 520 rpm.

The new procedure started on June 1, saves the government $1817 during the first year of operation.

Energy Programs

G. MERVIN AULT, DIRECTOR

The year 1976 has been a productive one for the Energy Programs directorate as a result of the joint efforts of our staff and the other R and T personnel and the Support personnel of Lewis.

The frontier of materials capability has been significantly extended and major advances made toward placing advanced materials into service. Oxide-dispersion-strengthened (ODA)-MiCrAl alloys have been shown to meet the requirements for advanced turbine-engine-vane application. These alloys have a 150°F higher temperature capability than current vane alloys and engine demonstration tests are currently underway at the General Electric Company.

Thermal barrier ceramic coatings have been developed with potential for use in high temperature components of aircraft and ground power gas turbines, reciprocating engines, and utility electric - power - combustion turbine engines. This concept has potential for increasing component life and cycle temperature and reducing coolant flow. The coating satisfactorily withstood over 500 cycles from 2500°F to flame out in ground engine tests. Lewis received an IR-100 award for the thermal barrier innovation.

Lewis composite technology has been adopted by Langley in its selection of the Lewis developed PMR-15 polyimide for use in its Composites for Advanced Space Transportation Systems (CASTS) program.

During the 1975-76 winter, the airborne radar ice information system developed by the Aerospace Applications Branch, in conjunction with the U. S. Coast Guard (Project ICEWARN) again helped in maintaining Great Lakes shipping throughout the winter. Members of the branch also initiated and carried out a similar ice information program during the brief summer along the Alaske North Slope. The Communications Technology Satellite (CTS) was used for data relay as part of this system. Because of the bad weather and cloudiness, which would have prohibited collection of ice information by conventional methods, the information provided by this new system was enthusiastically received and acclaimed by shippers.

Remote thermal scans of all NASA facilities throughout the country were successfully completed in 1976 with many diverse energy losses identified and verified. First year savings directly attributed to the thermal scanning program amount at least to $385K. Another million dollars of C&F funds for rehabilitation of heating systems at five NASA Centers.

The Radiations Applications Office staff succeeded in readying the Lewis Cyclotron for its proposed role in a study of cancer therapy using neutron bombardment with the Cleveland Clinic. Patient treatment will commence during 1977. The Lewis Cyclotron is the only one of the four cyclotrons being used for cancer therapy in the U. S. which will provide a vertical neutron beam to permit treatment in a horizontal position.

In the Fluid Physics and Chemistry Branch, an exact analytical solution was obtained for predicting the onset of flutter in fans and compressors with small blade loading. Analyses have predicted new phenomena relevant to compressor blade flutter which have been experimentally verified.

A group of grants and contracts supported and monitored by the Magnetics and Cryophysics Branch has yielded several new superconducting materials with excellent performance. These materials include Nb_3Ge and CyM_oS, which maintain zero electrical resistance at higher temperatures and higher magnetic fields, respectively, than any other materials. These materials are evaluated in the Lewis high-field magnets. A new liquid-neon cooled magnet of unique Lewis design is being fabricated in Lewis shops. It will produce the world's most intense steady magnetic field when completed next year.

Achievements in the controlled-fusion research program of the Plasma Physics Branch were lauded at an Awareness ceremony on December 3 for the laboratory-wide team that developed and brought into operation two unique superconducting magnet plasma research facilities: SUMMA and Bumpy Torus. Temperature and densities of the hot plasmas produced in these facilities are being optimized with the aid of laser and microwave density measurement systems developed this past year.

In the MHD generator program of the Plasma Physics Branch, several milestones were achieved: Power density has been increased an order of magnitude to over 2 MW/M^3 in our closed-cycle facility, our new combustion MHD facility using a 7T cryomagnet has been successfully brought into operation. Lewis contributions to MHD ground power plant studies have been recognized; the Lewis paper summarizing the ECAS MHD plant concept was the principal U. S. MHD paper at the US-USSR MHD Colloquium in Moscow this past October.

In the thermionic power generation program, the Lewis proposal of lanthanium hexaboride (LaB_6) as an excellent prospect for thermionic-converter electrodes was supported by results attained by contractor's research. A significant advance in heat-pipe technology was achieved this year when a Lewis-designed covert-groove tubing demonstrated over three times higher wicking capability and 16 percent greater heat-transport capability than an equivalent rectangular-grooved heat pipe.

Significant progress was made by our Chemical Energy Division in technology programs for an advanced reusable high pressure hydrogen-oxygen engine for orbit transfer behicle applications. Altitude performance and thrust chamber cooling tests, preburner firings, and full speed turbopump tests were completed. In supporting in-house work to improve thrust chamber low-cycle thermal-fatigue life, over 12,000 test firings were made at RETF evaluating materials, coatings, and test variables. In the vacuum chamber facility at RETF, seventeen space mission simulating cyclic tests were completed on a purged multilayer insulated liquid hydrogen tank which demonstrated purging effectiveness and reusable insulation system effectiveness. The Lewis high power Laser facility, a closed-loop, CO_2, continuous wave laser was completed. Its present output of 10 kW beam power was used in applications experiments focusing the beam to form a stable plasma in air and nitrogen. The Lewis fluidized bed facility, designed to study clean burning of sulfurized coal, and specifically the effects of the effluents on turbine materials, was also completed during the year.

In the Photovoltaic Tests and Applications Project, which Lewis manages as part of ERDA's National Photovoltaic Conversion Program, efforts this past year have concentrated on design, fabrication, and field installation of 18 solar cell-powered systems coupled to a variety of terrestrial applications. These applications have met the needs at remote sites for refrigeration (Isle Royal National Park for trail construction crews and the Arizona Papago Indian Reservation for medical supply storage) and electrical power for two live-in U. S. Forest Service fire lookout towers in California. Other systems developed this year have involved several DoD applications, a promotional display in Washington, D.C. of a solar cell battery charging System for electric vehicles, and two systems in India to power TV receivers for receipt of ATS-6 signals. A National Photovoltaic System Test Facility has been constructed in the West Area of the Center and is operational with about 10 kW (40 kW by Mid-CY '77) of electrical power from solar cells. Supporting activity involves system engineering, component development, improvements to terrestrial solar cell calibration methodology endurance testing of solar cell modules and materials, and the establishment of a national solar cell reference laboratory.

In the research efforts for space solar cells, carrier lifetime in the diffused region was measured for the first time and indicated that barriers limiting cell efficiency could be circumvented to achieve efficiencies in excess of 18%. Also, the validity of low cost solar cell automated production concepts was established by the fabrication of space quality solar cells without resort to vacuum processes.

In the ERDA Redox Project for the development of a new cost-competitive bulk energy storage system, one of the major problems of finding a membrane to separate the reactive oxidation-reduction solutions may be approaching resolution. A test facility capable of pilot system operating has been completed.

Tests completed on the aerospace silver-zinc cell developed by Lewis have demonstrated a wet life of less than 6 years and an energy density of 25 watt-hour per pound. Cells are now being evaluated at Lewis for the Ames Research Center as a possible power source candidate for a Jupiter planetary probe mission.

Research by the Materials Science Branch on hot corrosion, a destructive process in high temperature fossil fueled turbines, has identified the species in the flame that participate in the corrosion reaction as well as

(Continued on page 13)

It's a success!

Rocket lab tests low-thrust engine

Lewis rocket propulsion engineers scored a success recently when Lewis Director Dr. John F. McCarthy, Jr. pushed the start button on the first official test of the lab's new low-thrust rocket engine.

Unlike the large rocket engines that are used as boosters, the low-thrust engine in this program is being developed for use in deploying large, delicate structures in space.

This program differs in scale from another concept that would use a larger engine to do the same job. Both concepts are intended for use aboard the Shuttle.

The official test before a gallery of Lewis officials and engineers was a complete success. The firing of the 200-pound-thrust engine was everything the engineers had hoped for.

The test began when McCarthy pushed a button that activated a computer program which automatically fired the engine.

Observers and monitoring equipment were in building 100. The engine, with its volatile fuel supply, was fired in the engine test facility on the South 40, about one-half-mile away from the control room.

Observers in building 100 watched the test on several TV monitors. At the moment of ignition, a bright, red flame jetted from the nozzle, accompanied by a high-pitched sound caused by the rush of escaping gas.

In the second-long burn,

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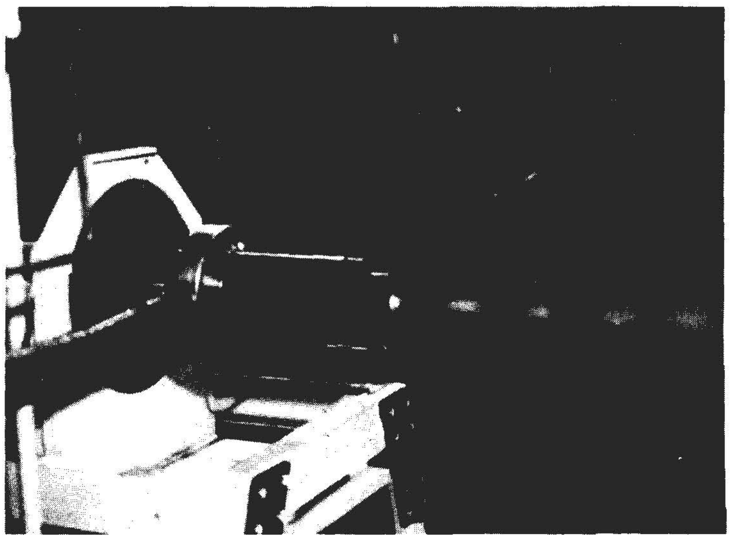


3...2...1...Fire!

A tongue of flame licks out of the nozzle of the Lewis low-thrust engine. (Dave Clinton photo)

INTELSAT launched successfully

Lewis' Centaur launch team successfully fired another Atlas-Centaur from Kennedy Space Center Thursday night, March 4, placing the fifth INTELSAT V satellite into orbit.

The communications satellite will provide for 12,000 two-way phone conversations and two channels of color TV to the 106 nations sponsoring the launch. The countries are members of International Telecommunications Organization, formed to provide multi-national satellite communications access.

The launch vehicle for the INTELSAT V was AC-58, a Lewis engineered Atlas-Centaur upper stage. NASA will be reimbursed for the costs of the launching by ITO.

Dr. John F. McCarthy, Jr. (left) and test controller Wayne Thomas at moment of firing. (Don Huebler photo)

Lewis tests engine...

(Continued from page 1)

the control center's computers gathered the required data.

Applause and hand shakes were followed by an invitation to see the engine at the test facility.

Future use of this technology should not be underestimated. The role of a low-thrust engine is to move gently a large, delicate object, such as a communications satellite with its solar panels and antenna extended, from low earth orbit into a higher one.

Engines used for such work must be very efficient and capable of long-duration burns.

The rate of acceleration is not as great with low-thrust engines as that of other, more powerful engines. But engineers say they need to give satellites only a gentle push over a long burn period to achieve a higher orbit.

The Lewis-engineered low-thrust engine will enable astronauts to pluck a satellite from the Shuttle orbiter bay and deploy it in space near the spacecraft. When everything deploys correctly, the low-thrust engine can boost it to the desired orbit.

Unlike the station keeping thrusters carried on spacecraft today, the low-thrust engine will be capable of the sustained operation required for changing orbits.

The engines, along with similar-purpose projects underway at other NASA centers, are commonly called "Orbital Transfer Vehicles." Lewis' contributions to the low-thrust engine field will be vital in building large structures in space.

Alive and roaring

Rocket Lab has enviable success record

Lewis' Rocket Engine Test Facility (RETF) is both the site of outstanding past achievements and the birthplace of future laurels.

Built in 1956 on land just outside the South gate, the facility permits Lewis to test liquid fuel engines ranging in thrust from 100 lbs. up to 20,000 lbs. at sea level atmospheric conditions.

Staff at the RETF work in one of the few such facilities remaining in the country. Similar test facilities are devoted to intensive development and testing of the Shuttle main engines or are closed down. Others are not in an operational state and would require extensive repair to become useful again.

technology and investigate seal and bearing performance at super-cold temperatures are underway.

The 40-acre site of the RETF is packed with storage tanks, cryogenic propellant tanks and test stands.

The main complex on the grounds is the rocket engine test stand facility. The complex of buildings and support equipment is located at the edge of a cliff above the Cleveland Metropark system.

Here, in special heavy-duty concrete sheds, are two static engine test stands. The stands permit firing of engines with complete instrumentation for data monitoring. The stands resemble barnyard water wells into which engines are fired downward. A complex system of water pipes and baffles cools the super-hot gases and suppresses high noise levels produced by the engines. Tests can last from a fraction of a second to about 100 seconds.

The exhaust muffler looks like a large metal chimney which projects out from the base of the building and turns upward to form the exhaust stack. A 400,000 gallon water tank provides the cooling water required for the muffler.

The test facility is considered one of the best because it permits scientists to test a variety of fuels, both

(Continued on page 2)

Rocket test facility...

(Continued from page 1)

liquid and high-pressure gas with a minimum of effort for conversion.

Tests are conducted frequently at the site, although you may not see anyone around at the time. The engineers are located in a control center within the main lab area. Monitoring of tests is done by TV cameras mounted in blast proof housings. Data collected during tests is controlled by a solid state sequence timer and processed through the main Lewis computer.

The facilities are impressive but the men and women who work there are the real story. Folks like Wayne Thomas have worked on projects that directly aided our space program. They are also involved in research that [illegible]

will make future rocket propulsion systems far more efficient than they are today.

The low-thrust engine program now underway in the RETF could result in engines that may help us to build large orbiting space stations and power collectors.

Technicians working on bearing and seal projects will make engines run for much longer periods without breakdowns or repairs.

Currently, the Shuttle main engines are restricted to 50 missions. By developing pumps and seals that will not wear out quickly in the super-cold environment of a cryogenic-fueled engine, the life of the engines can be greatly increased, according to Marty Braun, deputy chief of management support for [illegible] space propulsion.

"What we are doing here is similar to taking a high performance engine like that found in an exotic racing car and making it durable enough to be used in the family auto," Braun said.

The same type of research is in progress with the low-thrust engine program. Technicians and engineers are trying to make the tiny engines more efficient.

"The Shuttle main engines are about 99 percent efficient," said Thomas. "The bulk of Shuttle engine research is aimed at making them last longer. With the low-thrust engine we have to first make it more efficient. We must bring it from the current 93 percent efficiency level up to the 99 percent mark."

The next research step is to make it last a long time under repeated use, he added.

To achieve the goal, the lab is testing different fuels and methods of injecting them into the combustion chamber. A good portion of the research is also aimed at studying the effects of heating on the engine nozzle when it is running.

Whatever the task involved, Lewis can be sure that its rocket engine test facility can do the job.

major step forward for Lewis.

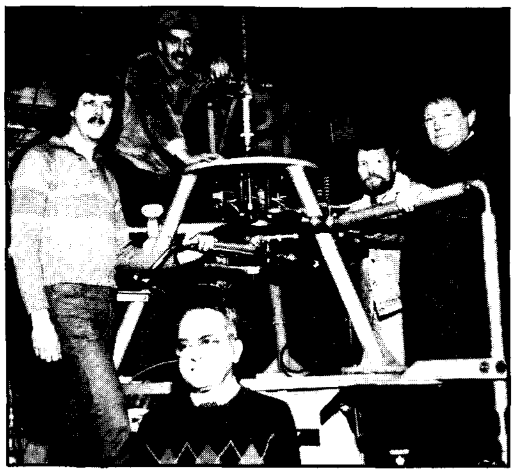
Space Propulsion

In chemical propulsion NASA's efforts on Space Station planning and propulsion requirements for large, flimsy, space systems has kept the emphasis on technologies applicable to station keeping and orbit transfer. Completed studies indicate hydrogen/oxygen expanded cycle type engines are one of the most promising for orbit transfer. In the thrust range up to 3000 lbs., this configuration provided high specific impulse and the largest operational envelope of the systems considered. Lewis is prepared to verify these and other analyses with the low-thrust test stand which came on line at RETF this year.

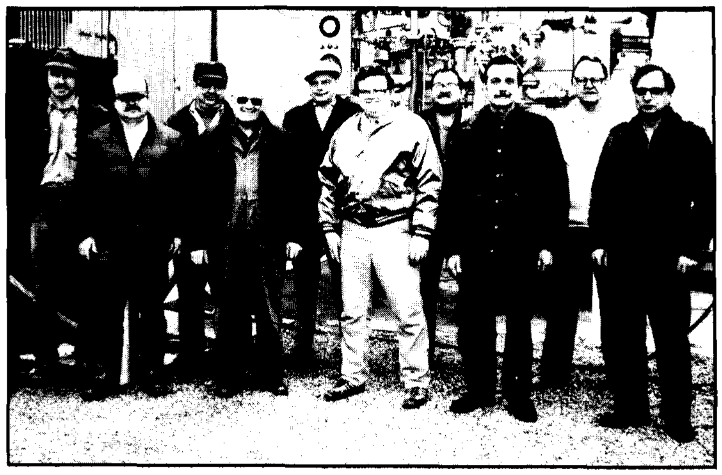
THRUST CHAMBERS

Major activities in the thrust chamber area are associated with enhancing the energy extraction from the propellants.

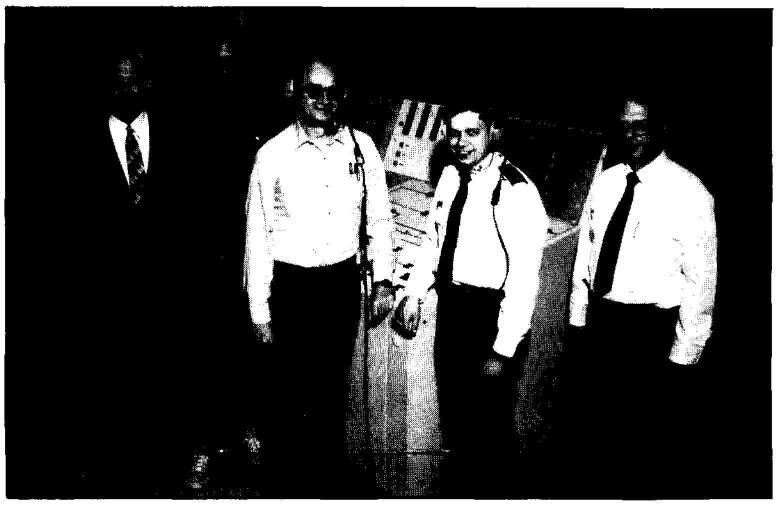
Standing, from left, George Repas, Harold Price and John Kazaroff, with Gary Halford (seated left) and Al Pavli are concerned with combustion chamber materials and chamber wall cooling.



Combustion chamber wall coatings evaluation is conducted at the "South 40" Rocket Engine Test Facility by (clockwise from 6 o'clock) John Kazaroff, Dennis Thompson, Bob Palaez, Clarence Wem, George Repas.



And (from left) by Jim Coy, Harry Jantz, Bill Lucas, Joe Romano, Harold Bulger, Bob Collins, Dick Kajack, Gary Faldon, Tom Dilling and Milan Jopek.



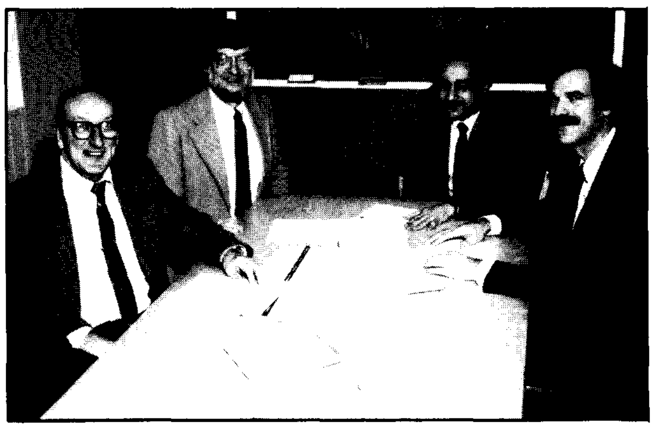
Facility operation and test monitoring is conducted in the ROB Control Room by Wayne Thomas, (left), Wendall White, Ed Krawczonek, Mark Klem, Dick Quentmeyer.

And by (seated l-r) Neal Wingenfeld, Joe Etzler, and (standing l-r) Jim Giomini and Terrell Jansen.

PROGRAM MANAGEMENT

These people are involved in SSME and OTV programs.

From left Greg Reck, Jody Getz, Don Petrash and Sol Gorland.

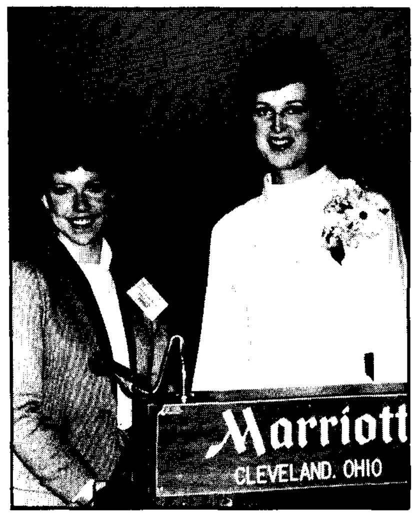


From left Pete Wanhainen, Carl Aukerman, Sol Gorland and Greg Reck.

PROCUREMENT

The OTV has a number of large contracts handled by this group: (from left), Shirley Boyer, Reggie Paginton, Tony Long, Larry Cooper, Fran Driscoll, and Dori Sharp.

These are the people who handle the contracts and grants for the SSME program. From left, Kurt Brocone, Mary Kovach, Boyd Bane, Willie Fleming, Tony Long, Glen Williams and Sol Gorland.



Debbie Ryan Rachul (left) was the coordinator for the OTV Propulsion Conference held in the DEB on April 3-4, 1984. Donna Sexton of Martin Marietta Denver Aerospace spoke at the dinner about the Manned Maneuver Unit used for the Solar Max repair on the recent Shuttle flight.

LEWIS AWARENESS

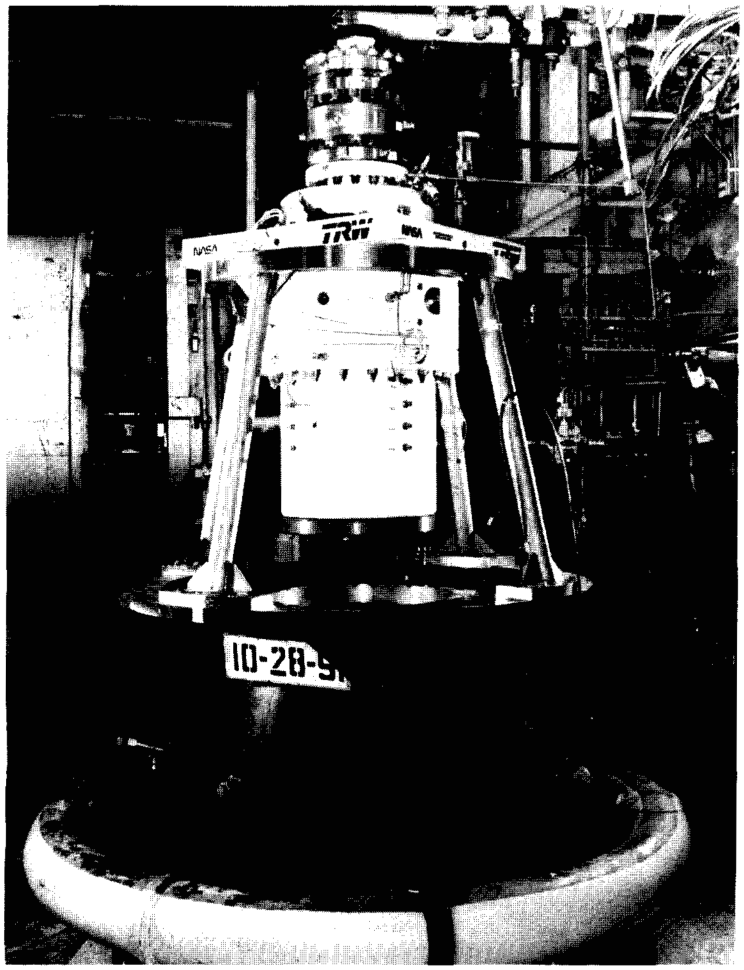
Awareness photos by John Marton.
Design and artwork by Charles Meyers.
Team Leads: Marty Braun, Stan Marsik, Larry Cooper.

Teaming Up With TRW

Lewis Advances Low-Cost Space Access

In order for the United States to counteract fierce foreign competition in the commercial launch vehicle arena, studies have shown that a new cost-effective launch system is required in order to maintain U.S. viability in space access. The French Ariane 4 is already highly competitive, and the new Ariane 5 system is projected to operate at least 20 percent below comparable U.S. systems and will dominate the free market by 1996. Nations such as China and Russia are already using low-cost technology and have developed reliable and competitive launch vehicles. A new, European government-supported consortium may soon compete and even dominate the commercial space market. For the U.S. commercial launch industry to remain competitive, a low-cost launch vehicle must be developed to place payloads into low-Earth orbit for under $1000 per pound.

Rising to this challenge, Lewis, in a joint effort with TRW Space & Technology Group, has successfully completed the first phase of testing on the Low Cost LO_X/LH_2 Rocket Engine Demonstration Program. In response to the 1984 Space Commercialization Act, Lewis and TRW entered into a Space Act Agreement to demonstrate that the pintle-injector engine can operate at acceptable stable performance levels and to demonstrate the life of a low-cost ablative liner combustion chamber using liquid oxygen/hydrogen (LO_X/LH_2) propellants for a proposed commercial launch vehicle. The testing of a subscale 16,400-pound thrust engine was performed at the Rocket Engine Test Facility from December 1991 through March 1992.



In a joint effort with TRW Space & Technology Group, Lewis has successfully completed the first phase of testing on the Low Cost LO_X/LH_2 Rocket Engine Demonstration Program.

"The recently completed testing of TRW's 16,400-pound thrust liquid oxygen/liquid hydrogen pintle-injector rocket engine was an unqualified success. It demonstrated that high performance and excellent combustion stability could be achieved using a technology well-suited to the production of a new generation of low-cost booster engines that will reduce the cost of access to space," said Frank Stoddard, TRW program manager.

Trade studies performed by McDonnell-Douglas and TRW have shown that a low-cost commercial expendable launch vehicle could be designed using low-pressure turbopumps and rocket combustors. These studies show that expensive high-performance technology can be sacrificed for inexpensive lower performance technology and still meet mission requirements. Because the propulsion system is more than half of a launch vehicle's cost, TRW proposed the pintle-injector engine design used in the Apollo Program's lunar module descent engine.

TRW's proposed engine will run on liquid hydrogen and liquid oxygen and use low-pressure, low-cost turbopumps to supply the engine propellants. The engine consists of a centrally located coaxial pintle injector, an ablative liner for insulating the metal surfaces of the combustion chamber and nozzle, and simple translating annular sleeves to throttle the propellant systems. The engine has few moving parts.

"We are indebted to all the Lewis people who worked so hard to make these tests such an outstanding success," said TRW's Stoddard.

According to Donald Urasek, Space Propulsion Division, Lewis used a matrix team approach to accommodate TRW. The team was composed of personnel from the Space Propulsion and Technology Division, Test Installations Division, Computer Services Division, Fabrication Support Division, and TRW. The engine was built by TRW, and Lewis personnel designed the engine support hardware, modified the test facility and propellant support systems, and altered the data recording/data reduction techniques for accommodating the engine testing. The test results confirmed the analyses and conclusions that a low-cost and low-development risk solution is attainable with simpler engines. The results from the testing show that the engine delivered 96-98 percent combustion efficiency, about two to four percent higher efficiency than what was expected and what was used in the trade studies.

"The higher than expected performance and excellent stability characteristics show that this is an exciting engine concept for providing low-cost access to space," said Mark Klem, Launch Vehicle Propulsion Branch.

TRW now plans to build and test-fire a scaled-up engine with 40,000 pounds of thrust. Following that, they plan to test-fire the 16.4K engine, utilizing low-cost, modified low-pressure aircraft turbopumps. A full scale, 750,000-pound thrust engine will be designed for testing as well.

"The TRW joint program is a model example of successful cooperative work between Lewis and industry which we hope to duplicate more and more in the years ahead. In it, both parties made special commitments to gain and share new information and move new technologies more rapidly to application," said Dr. J. Stuart Fordyce, deputy director. "NASA gained experience with pintle injectors and engine instabilities. TRW gained information to guide and improve their cryogenic pintle injector testing. Both Lewis and TRW engineers and technicians worked long hours, side-by-side, to accomplish the effort and meet the goals within the time frame and budgeted cost estimate."

A new cost-effective launch system will help the United States counteract fierce competition in the launch vehicle arena.