ENVIRONMENTAL ASSESSMENT

for the

American Rocket Company's Hybrid Rocket Motor Testing at Stennis Space Center

August 11, 1993

Submitted to:
SSC Environmental Office
John C. Stennis Space Center
National Aeronautics and Space Administration
Stennis Space Center, MS 39529-6000

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LIST OF ABBREVIATIONS

AFB	Air Force Base
AL_2O_3	Aluminum Oxide
AMROC	American Rocket Company
ASRM	Advanced Solid Rocket Motor
BR	Burn Rate
CA	California
CATEX	Category Exclusion
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CTF	Component Test Facility
DOD	Department of Defense
EA	Environmental Assessment
EAFB	Edwards Air Force Base
FONSI	Finding of No Significant Impact
GOx	Gaseous Oxygen
H_2O	Water
HTPB	Hydroxyl-Terminated Polybutadiene
HCL	Hydrogen Chloride
ITAS	Independent Test Article Structure
lbf	Pound Force
LOx	Liquid Oxygen
NASA	National Aeronautics and Space Administration
PL	Phillips Laboratory
PM	Particulate Matter
NEPA	National Environmental Policy Act
NOx	Nitrogen Oxides
SSC	John C. Stennis Space Center
VAFB	Vandenberg Air Force Base
VOCs	Volatile Organic Compounds
10K	10,000

1.0 SUMMARY AND CONCLUSIONS

1.1 Introduction

Beginning in 1993, the American Rocket Company (AMROC) and the John C. Stennis Center (SSC) plan to test hybrid rocket motors at SSC's facilities. Hybrid rocket motors solve many of the safety and environmental concerns facing solid rocket motor manufacture, test and operation, yet deliver performance comparable to liquid rocket engines with much less hardware and operational complexity. AMROC's hybrid propulsion is unique from solid and liquid propulsion in that it has negligible environmental impacts and reduces health and safety hazards during all phases of development, manufacturing, integration, test and operation. The motor propellants, manufacturing processes and test operations are designed to have negligible environmental impacts. AMROC's hybrid fuel is inert and utilizes non-toxic, safe and clean propellants. Since hybrid rocket technology is important to both the National Aeronautics and Space Administration's (NASA) and AMROC, NASA's SSC and AMROC will be working together to test hybrid rocket motors at SSC.

NASA's John C. Stennis Space Center was originally established to perform development and acceptance testing of large rocket engines in support of the United State's Space Program. SSC's mission, as NASA's primary rocket engine test facility, is expanding with current program needs for development and testing of solid, liquid and hybrid rocket propulsion systems and critical engine and launch vehicle components. SSC possesses considerable expertise in propulsion testing, coupled with the adaptability of existing test facilities to meet the demands of developing propulsion technology; especially hybrid propulsion technology.

AMROC is a small commercial company that is involved in the development of hybrid rocket propulsion; and is dedicated to reducing the cost of accessing space by commercializing low-cost hybrid rocket propulsion for use on space launch vehicles. Since 1985, AMROC has developed hybrid rocket motors with thrust levels from 60 lbf to 250,000 lbf thrust. AMROC is currently seeking to expand its commercial hybrid rocket motor development and test capabilities using existing and complementary resources at NASA.

1.2 Proposed Action

AMROC proposes to test AMROC's small, laboratory-class, "burn rate" hybrid motors and 10,000 lbf (10K) thrust motors at the existing Component Test Facility (CTF) at SSC. The Burn Rate (BR) motors are gaseous oxygen-fed hybrid motors that will be used by AMROC to measure fuel regression rates. The 10K motors are liquid oxygen-fed hybrid motors that will be used by AMROC to evaluate motor and subsystem performance. BR and 10K motor testing are low-cost, quick and effective methods for developing the technologies required for larger

hybrid rocket motors. AMROC will use this test data to assist in designing larger thrust, commercial, hybrid rocket motors.

The proposed action covered by this environmental assessment is the modification of the CTF and the testing of BR and 10K hybrid motors at the CTF. The CTF can be easily configured to accommodate hybrid rocket motor testing. The hybrid motor testing is planned to begin in September 1993 with a maximum frequency of 100 burn rate motors per year and ten 10K motors per year.

1.3 Alternative Actions

Although AMROC has an existing hybrid rocket motor test capability at Phillips Laboratory, Edwards AFB, it is AMROC's and NASA's desire to use existing facilities and surplus assets at SSC to create a complementary hybrid test capability to further serve industry and government needs. SSC has some unique test capabilities primarily in the area of exhaust plume characterization and data measurement that will be used in this program. There are a few other facilities within SSC, other than the CTF, that could be used for BR and 10K hybrid motor testing. AMROC and SSC have toured and reviewed these facilities and have determined that the existing CTF is well suited for and will require minimal modifications for BR and 10K motor testing.

1.4 No-Action Alternative

The no-action alternative would preclude the modification and operation of a BR and 10K hybrid motor test capability at SSC. This action would limit AMROC's ability to develop and test hybrid rocket motors. A no action alternative would negatively impact AMROC's ability to develop hybrid propulsion for commercial, DOD and NASA launch vehicles, and would not be in the spirit of the nation's established policy under the Commercial Space Act of 1984 to support commercial space activities with excess government facilities and surplus equipment. A no-action alternative would also delay the potential benefits to the environment gained by replacing solid rocket technology with more environmentally benign hybrid boosters.

1.5 Environmental Consequences

The environmental impacts identified as a result of this assessment are insignificant. The existing CTF facility will be modified with new, small test stands which will not require any ground breaking or new construction. Only mechanical, electrical and fluid equipment will be modified and/or reconfigured for the testing.

AMROC's hybrid motor fuels use non-toxic and non-explosive materials and propellants; and have no metals or oxidizers in the fuel. Unlike solid rocket motors, AMROC's hybrid motors do not emit any hydrogen chloride (HCL) or aluminum particles (AL_2O_3) in the exhaust throughout its operation. The primary hybrid motor exhaust products are water, carbon dioxide, carbon monoxide and hydrogen. The cumulative amounts of exhaust products due to BR and 10K motor testing will have an insignificant impact on the local environment. Air emissions for the 10K motor ignition includes a minor amount of aluminum oxide from the triethylaluminum ignitor. Process waste water (applicable for BR motors only) consists of a minor amount of non-contact cooling water. No other matters of potential environmental concern have been identified.

1.6 Recommendation

Since there are insignificant environmental impacts due to hybrid motor testing, the recommendation is that a Finding of No Significant Impact be made for AMROC's BR and 10K motor testing at Stennis Space Center.

2.0 PURPOSE AND NEED FOR PROPOSED ACTION

AMROC is a commercial aerospace company whose near-term goal is to bring hybrid rocket propulsion to flight status for use on DOD, NASA and commercial space launch vehicles. Towards this goal, AMROC is involved in the development of hybrid rocket motors ranging from 150 lbf to 250,000 lbf thrust. Currently, AMROC is seeking to expand its commercial BR and 10K hybrid rocket motor test capabilities at SSC.

SSC has a desire to expand its current rocket propulsion test capabilities to include testing of hybrid rocket motors. This hybrid test capability will serve the both the needs of NASA and AMROC.

The objective of testing BR motors is to measure fuel regression rates and to experimentally verify the exhaust constituents of hybrid rocket motors. BR motors are an effective method for characterizing the regression rate of fuel formulations and materials in the hybrid combustion environment. A test program is proposed that will explore hybrid fuel formulations, verify material performance and observe combustion stability.

The objective of testing 10K motors is to measure the performance of the hybrid fuel grain at a scale larger than the BR motor, and to explore the operating characteristics of various motor components such as nozzles and injectors. A test program that uses various fuel grain, injector and nozzles designs operating at various conditions will be used as a technology test bed for use on larger hybrid rocket motors.

An Environmental Assessment for BR and 10K hybrid motor testing operations is submitted herein to comply with the requirements of the National Environmental Policy Act.

3.0 DESCRIPTION OF PROPOSED ACTIONS AND ALTERNATIVES

3.1 Environmental Issues and Hybrid Propulsion

Hybrid propulsion is unique from solid and liquid propulsion in that it has negligible environmental impacts, and unprecedented reduction in safety and health hazards during all phases of development, manufacturing, assembly, test and operation. Standard industrial safety practices and simple environmental analyses have been sufficient to ensure safety and environmental compliance with Local, State, Federal NEPA, DOD and NASA regulations.

AMROC's hybrid motors use a solid hydrocarbon fuel, called hydroxyl-terminated polybutadiene, lining a combustion chamber, and a gaseous or liquid oxygen oxidizer which is stored in a separate tank as shown in Figure 1. The hybrid rocket motor burns like a wood fire, that is, directly above the surface of the fuel. The oxidizer is sprayed into the forward end of the combustion chamber and is heated initially by an electric ignition for the BR motors or a 500 millisecond charge of triethylaluminum fluid for the 10K motor ignition. Hot oxygen vapors flow down the combustion port, vaporizing the fuel which mixes and burns in a combustion flame that sits above the fuel and thus the process is self sustaining, as long as oxygen is available to continue combustion. The process is controlled by the flow of oxygen down the combustion port. Less flow, less thrust. No flow, no combustion and thrust is terminated.

Due to the benign nature of hybrid rocket motors, standard industrial safety procedures can be used for all test operations. Unlike solid rocket motors, hybrids do not require any special handling safeguards or remote facilities during handling and test operations. A detailed description of the hybrid rocket motor test operations can be found in References 1 and 2.

The hybrid fuel consists of a synthetic polybutadiene rubber with a carbon black additive which results in a product that is almost identical to the rubber used in automobile tires. The primary fuel components are polybutadiene, isocyanate curatives, carbon black, and a defoamer. The materials and the cast fuel are inert and can not detonate. All of the individual materials and cast fuel are classified as either an industrial flammable or combustible material. The Vandenberg AFB Safety Office has rated the hybrid fuel as having a zero TNT equivalency as shown in Reference 3.

One of the primary reasons AMROC selected hybrid propulsion is because hybrid motors are environmentally benign, clean and safe to manufacture, handle, test, process and operate. AMROC's BR and 10K hybrid motors use non-toxic and non-explosive materials and propellants; and have no metals or oxidizers in the fuel. A photograph of a small 150 lbf thrust Burn Rate hybrid motor test is shown in Figure 2.

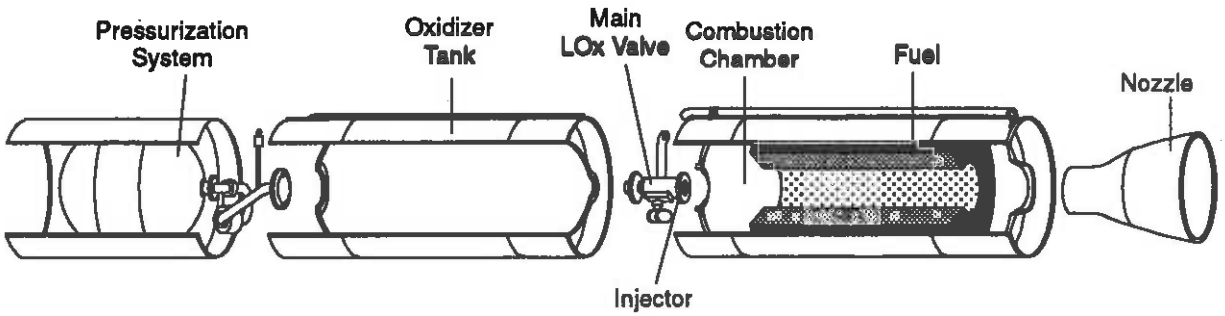

Figure 1. A Sketch of a Classical Hybrid Rocket Motor

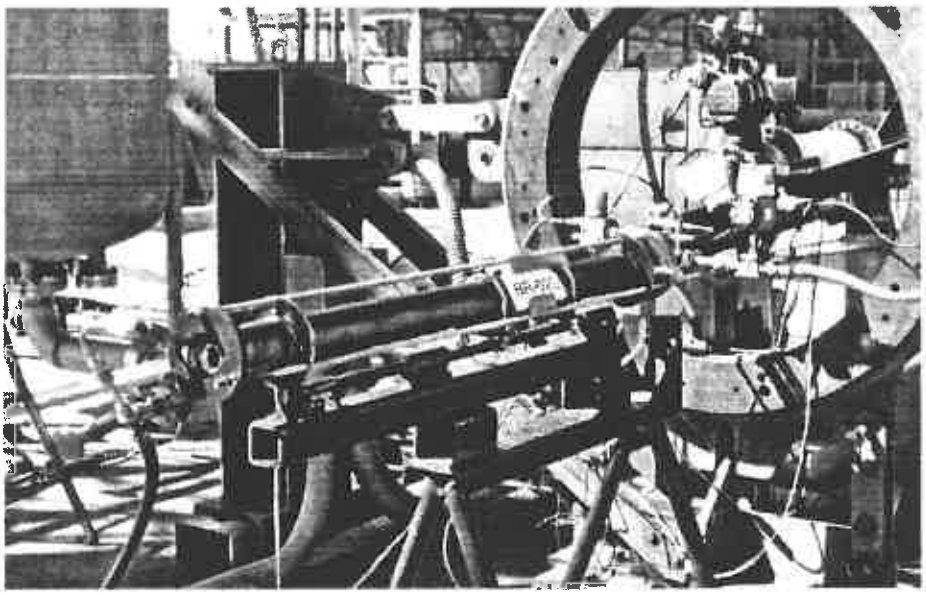

Figure 2. Burn Rate Hybrid Rocket Motor Test

AMROC's motors do not emit any hydrogen chloride (HCL) or aluminum particles (AL_2O_3) in the exhaust. The primary exhaust products are steam (H_2O), carbon dioxide (CO_2), carbon monoxide (CO) and hydrogen (H_2). Some carbonaceous soot will be formed as a result of incomplete combustion of the fuel. Afterburning of the exhaust gas will cause additional carbon dioxide and nitrogen oxide emissions as small, trace emissions. Table 1 outlines several key environmental issues as they relate to hybrid rocket motor manufacture, test and operation.

Table 1. Environmental Issues for Hybrid Propulsion

Environmental Issue	AMROC's Approach	Benefits
Significant Environmental Impacts During Manufacturing and Test Operations Requiring EIS and Mitigation Measures	All Materials, Propellants and Processes are Designed for Negligible Environmental Impact	All AMROC's Activities Have Obtained CATEX or FONSI under NEPA EA Process; No Significant Impacts on Air, Land, Water, People, Animals
New Facility Construction and Its Impact on Environment, Habitat and Archeological Resources	No New Facilities; Will Use Existing Facilities With No Problems Anticipated During EA Process	Hybrid Motors and Facilities Approach Streamlines EA Process and Reduces Environmental Non-Compliance Risk
Propellant Leaks During Test Operations	Solid Polybutadiene Fuel Can Not Leak; GOx or LOx Released to Atmosphere is Breathable Oxygen	No Regulatory or Environmental Liability Problems at Test Site
Toxic Propellants (Exposure at Test Site)	No Toxic Hybrid Fuels or Oxidizers; Small Amount of Hazardous TEAL used for Ignition	Fewer Test Restrictions; More Favorable Insurance Status
Explosive Hazard of Motors at Any Point in Process	Non-Explosive Hybrid Motors	No Regulatory or Environmental Liability in Case of Accident
Hydrochloric Acid and Aluminum Oxide Particles in Rocket Exhaust	No HCL or Aluminum Oxide Particles in Propellant or Exhaust During Burn; Minor Amounts of Aluminum Oxide During Ignition	Reduces Health, Regulatory and Liability Risks

All of AMROC hybrid motor production, test and launch operations have either received a Category Exclusion (CATEX) or a Finding of No Significant Impact (FONSI) under the NEPA process. There are no significant environmental impacts on air, land, water, animals, people or habitats during any phase of hybrid motor production, test and flight. It is expected that all of the burn rate motor and larger hybrid motor testing at SSC will have a negligible impact on the environment.

References 4-6 are important environmental documents that relate to the planned effort at SSC. The San Bernardino County, California Air Pollution Permit, that satisfies all of the environmental requirements for testing hybrid motors at Phillips Laboratory, Edwards AFB, is given in Reference 4.

3.2 Description of Proposed Actions

AMROC and SSC, in a joint effort, will be testing small, laboratory class, Burn Rate (BR) and 10,000 lbf (10K) thrust hybrid rocket motors at the Component Test Facility at SSC. The BR motors are gaseous oxygen/polybutadiene hybrid rocket motors that develop thrust in the range of 150-1,000 lbf of thrust. The 10K motors are liquid oxygen/polybutadiene hybrid rocket motors that have thrust levels from 5,000-10,000 lbf thrust. The proposed action of this EA is the modification of the CTF facility for the testing of the BR and 10K motors at SSC. This action is a research and development activity that will assist in the development of hybrid rocket propulsion for the government and industry.

The CTF facility is located at SSC as shown in Figure 3. The Component Test Facility layout is shown in Figure 4 and is described in detail in Reference 7.

The modifications performed at the CTF site will be to install small test stands for the BR motors and the 10K motors, and the associated fluid support systems. The test stands will be installed on the existing Independent Test Article Structure (ITAS). The CTF modifications for the BR test stand will be complete in August 1993 and the modifications for the 10K test stand will be complete in January 1994. For a more detailed description of the CTF facility see Reference 7.

The test operations will commence once the test stand is modified and all air permitting issues with the State of Mississippi are resolved. The BR motor testing is a very simple process that is as follows: (1) attach the motor to the test stand, (2) attach the GOx feed system to the motor, (3) attach the ignition system (electric for BR motors, TEAL for 10K motors), (4) load GOx in the run tank, and (5) begin testing sequence. The typical duration of a BR motor test is 20 seconds. The maximum annual testing rate for the BR motors is 100 motors per year.

The 10K motor testing is also a very simple process that is as follows: (1) attach the motor to the test stand, (2) attach the LOx feed system to the motor, (3) attach the ignition system, (4) load LOx in the run tank, and (5) begin testing sequence. The typical duration of a 10K motor test is 45 seconds. The maximum annual testing rate for the 10K motor is 10 motors per year.

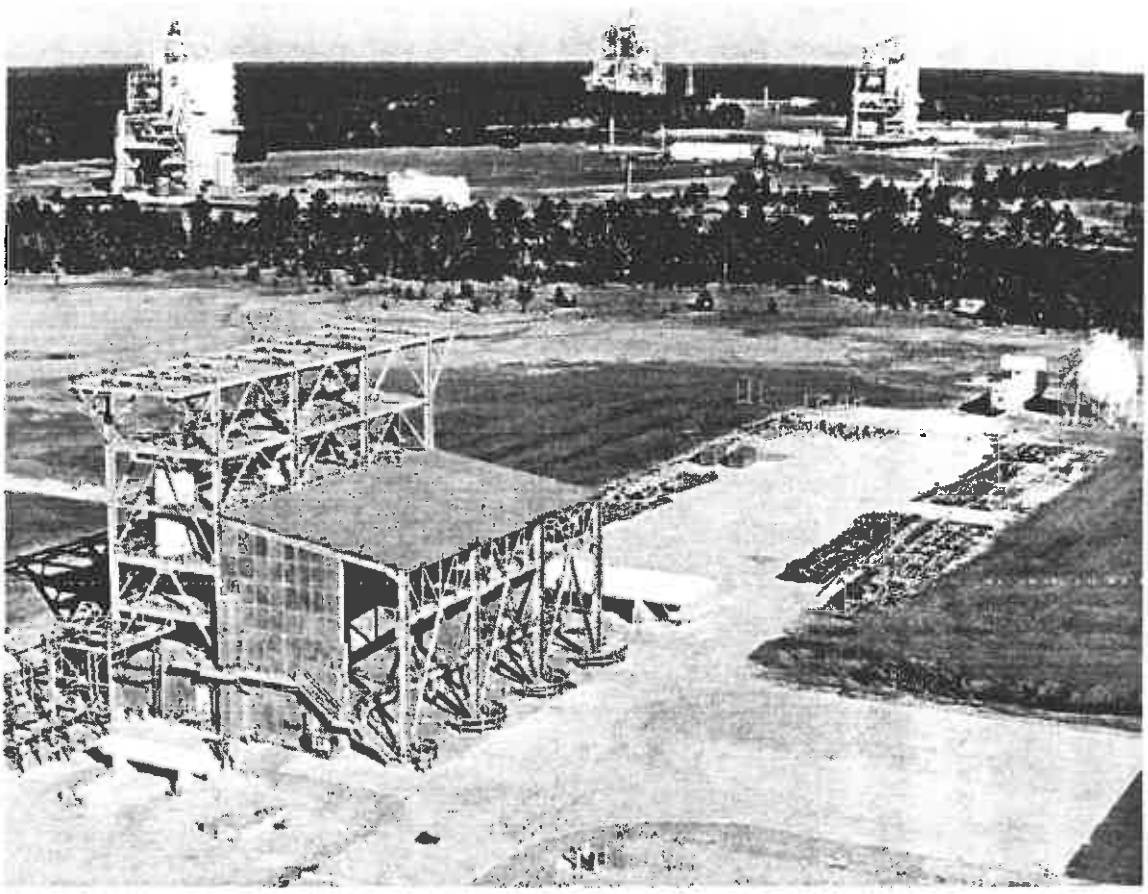

Figure 3. Location of the Component Test Facility at SSC

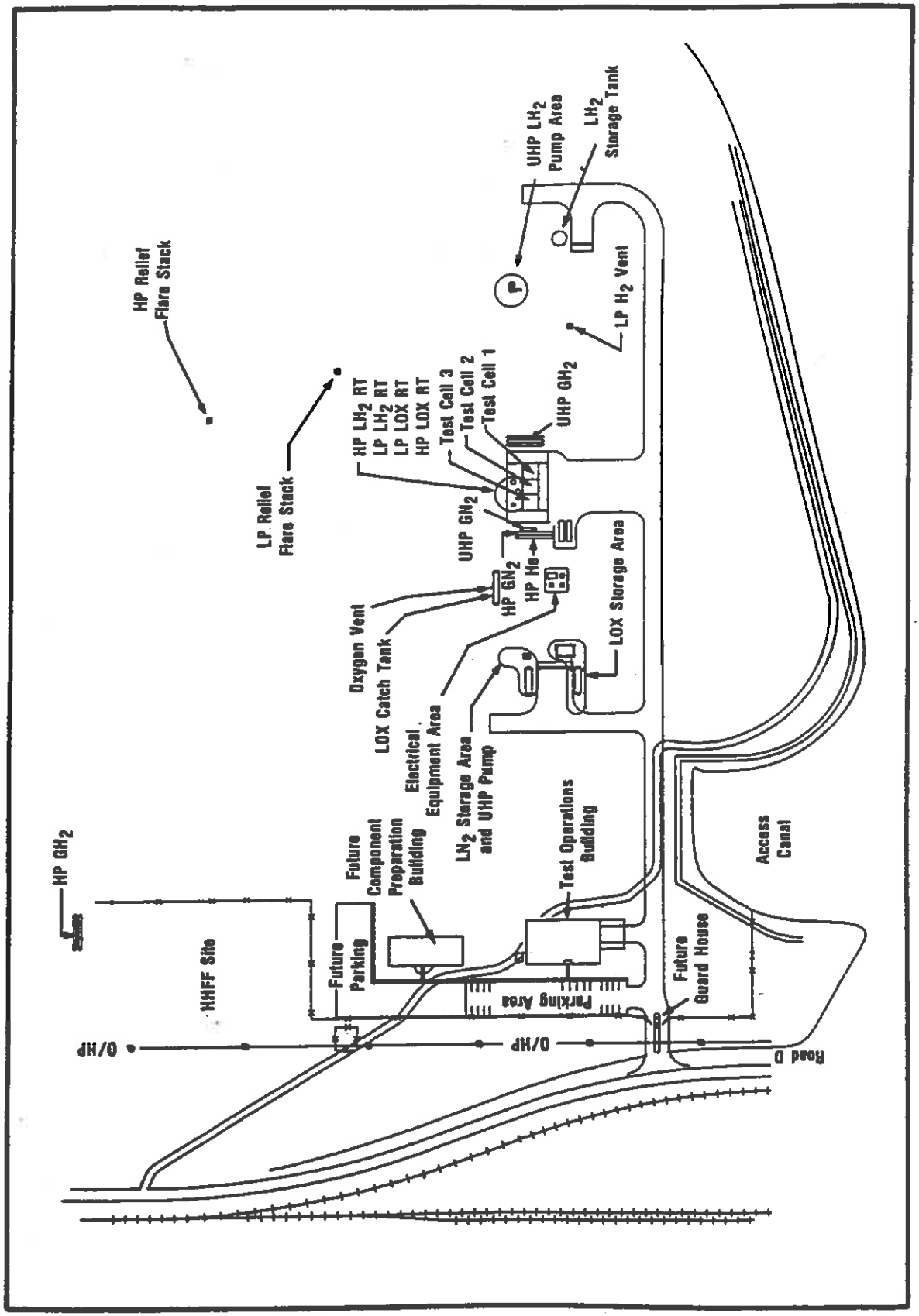

Figure 4. Layout of the Component Test Facility

3.3 Description of Alternatives

3.3.1 Other Locations

Currently, AMROC operates a hybrid propulsion test facility at Phillips Laboratory (PL) Test Site 1-56 at Edwards AFB, California. Other sites, in addition to the PL site, have been evaluated by AMROC for BR and 10K hybrid motor testing. This evaluation was based on instrumentation and diagnostic capability, support infrastructure, manpower, existing test facilities and cost effectiveness. SSC's Component Test Facility fulfills AMROC's commercial need for a new low-cost test facility that has unique measurement and diagnostic capabilities for assessing motor performance and exhaust plume constituents. In addition, creating a hybrid test capability at SSC's CTF fulfills a NASA desire to expand the hybrid test capability in the U.S.

3.3.2 Onsite Locations

Two potential SSC test locations were evaluated as shown in Table 2. Since the evaluation, SSC, in the interest of cost effectiveness, has decided to move the DTF to the CTF. This move consolidates test facilities and test crews and provides a more flexible, expandable test facility for plume diagnostics and engine testing. This move provides the infrastructure at CTF to fulfill the BR and 10K motor test requirements with minimal facility reconfiguration and provides negligible impact on the local environment. The CTF is specifically designed for testing hybrid or liquid rocket motors. The remaining test facilities at SSC are primarily for testing large rocket motors and may be used in the future for large hybrid rocket motor testing.

Table 2. Possible BR and 10K Motor Test Locations at SSC

Location	Advantages	Disadvantages
Diagnostic Test Facility (DTF)	• DTF Designed for Small Hybrid or Liquid Rocket Testing • GOx and GN2 Fluid Systems Exist • Test Pad Exists • Data Collection System Exists • Facility Power Exists • Designated Non-Wetland Area	• New Small Test Stands Need to be Installed • Limited Quantity Distance Arcs • Interference With Other Critical Systems (High Pressure Gas Facility)
Component Test Facility (CTF)	• Existing Test Cells or Pads • Specifically Designed for Rocket Motor or Component Testing • Wetland Areas Already Mitigated • Modern Facility, More Flexible and Expandable • Economically More Feasible for Test Operations	• None After DTF Move Completed

3.4 No Action Alternative

The no-action alternative will result in no impacts on the environment from the CTF facility upgrade and test operations. The no-action alternative would not be in the spirit of the nation's established policy to seek and encourage the fullest commercial use of Space under the terms of the Commercial Space Act of 1984 and amended in 1988 (Reference 8). This includes any activity related to the development or operations of U.S. expendable launch vehicles. Under a no action alternative, SSC would deny AMROC continuing use of an excess NASA facility for hybrid motor testing. This action would cause delays in AMROC's hybrid propulsion program and possibly damage a significant effort in commercializing Space and adversely impact the future space launch capability of the U.S. A no-action alternative would also delay the use of hybrid boosters for space launch vehicles. This application of hybrids could potentially alleviate the current environmental impact of solid rocket boosters.

4.0 DESCRIPTION OF THE AFFECTED ENVIRONMENT

4.1 Summary

Throughout its history, SSC has been used for the development and testing of rocket propulsion systems for space launch vehicles. AMROC's new hybrid propulsion is unique from solid and liquid propulsion in that it minimizes environmental impacts, and safety and health hazards during all phases of development, manufacturing, integration, test, launch processing and operation.

This section summarizes the environmental effects resulting from the CTF facility upgrade and the testing of BR and 10K hybrid motors. The facility upgrade will have a negligible impact on the surrounding environment.

Air releases from the BR and 10K motors consist of small quantities of water, carbon dioxide, carbon monoxide and hydrogen. The single point source and the annual cumulative amounts are extremely small. Noise levels from the 10-50 second tests will be comparable to noise levels for small liquid or solid rocket motors. The testing of hybrid rocket motors at SSC poses an insignificant environmental impact on wildlife and people, and on the surrounding air, water, land and habitat environments.

4.2 Air Quality

A hybrid motor typically consists of a polybutadiene (i.e. rubber material) and an oxidizer (i.e. typical gaseous oxygen or liquid oxygen). The two propellants are stored in separate chambers and, in general, the solid fuel will not burn in the absence of the liquid oxidizer. Since hybrid rockets use one propellant as a liquid and one as a solid, they exhibit similar features of both liquid and solid propellant systems. However, emissions from hybrid systems are environmentally cleaner as a result of the cleaner burning fuel characteristics of the polybutadiene and liquid oxygen oxidizer. For the larger hybrid propellant systems, a small amount of hypergol, such as triethylaluminum, will be used for ignition purposes. Emissions from the ignitor combustion are released with the propellant combustion byproducts.

Emissions from a hybrid using HTPB and LOx are primarily water, carbon dioxide, carbon monoxide and hydrogen. Some carbonaceous soot will be formed as a result of incomplete combustion of the fuel. Afterburning of the exhaust gas will cause additional carbon dioxide and nitrogen oxide emissions as secondary emissions. For the 10K hybrid motors, a small amount of aluminum oxide (< 0.5 lbs) will be released as a result of the ignition sequence. Approximately 3-6 ounces of TEAL is injected for ignition over a 500 millisecond to 1 second period per test. Only one 10K motor test is proposed per day. Emissions from the combustion of BR and 10K hybrid motors are shown in Table 3.

Table 3. Burn Rate and 10K Hybrid Motor Emissions

Thrust Class	Engine Type	Propellant Weight (pounds)	Burn Duration	Test Frequency Per Year	Emission Type	Point Source Amount (lbs/test)	Annual Amount (lbs/yr)
BR Motor (1,000 lbf)	Hybrid GOx/HTPB Electric Ignitor	60 Total 20/40	20 seconds	100	PM CO NOx VOCs	trace 25 <1 <1	trace 2,500 <50 <1
10K Motors (10,000 lbf)	Hybrid LOx/HTPB TEA Ignitor	1,676 Total 551/1125 <0.5	45 seconds	10	PM CO NOx VOCs AL2O3	trace 670 10 <1 trace	trace 6,700 100 <1 trace

Emissions based on theoretical calculations. Hybrid combustion byproducts assume some afterburning. Particulate matter will be in the form of carbonaceous soot. For the 10K hybrid motor, trace amounts of aluminum oxide will be present due to the igniter system (<0.5 lbs triethylaluminum per test). Other combustion byproducts include hydrogen, carbon dioxide and water. GOx is gaseous oxygen. PM is particulate matter. CO is carbon monoxide. NOx is nitrogen oxide and VOCs is volatile organic compounds.

The BR and 10K motor testing represent a small point-source and annual emission of CO into the local environment.

As part of the testing program, detailed plume diagnostic measurement programs are proposed to determine the characterization of the combustion process and its relationship to motor performance. Measurements made in conjunction with these studies will provide substantial data directly applicable to environmental conditions including soot formation, carbon monoxide/carbon dioxide relationships and particle distribution.

4.3 Water Quality

Industrial water will be supplied for nozzle coolant in the BR motors and fire protection for both BR and 10K motors. The non-contact coolant water for the BR motor will not have any materials transferred to it and can be collected into a closed collection system. There is no anticipated creation of waste water or impact on the water quality at or near the CTF facility.

4.4 Wetland and Floodplain Impacts

Since the existing CTF facility will be used for the testing operations, there are no anticipated impacts on the wetland or floodplain.

4.5 Biotic Resources

A detailed description of the biological communities located at SSC are given in the SSC Environmental Resources Document (Reference 9). Since the existing CTF facility will be used for the testing operations, the will be no construction or habitat loss during the proposed activity. The small quantities of hybrid rocket motor air emissions of water vapor, carbon monoxide, carbon dioxide and hydrogen pose a negligible impact on the local flora and fauna.

4.6 Threatened and Endangered Species

Threatened and endangered species surveys recently performed on the ASRM site near the CTF facility are given in the terrestrial fauna report of Drs. Edmund Keiser and Paul Logo (Reference 10) and the botanical studies of Dr. Jean Wooten (Reference 11). Since the hybrid rocket motor testing operations at the existing CTF will not require new construction with the loss of habitat, there should not any adverse effect on any species habitat at or near the CTF.

4.7 Waste Generation, Treatment, Storage and Disposal

No hazardous or toxic waste streams will be generated during any of the CTF hybrid rocket motor operations.

4.8 Toxic Substances

No toxic materials, hybrid fuels, or oxidizers are used in the BR or 10K hybrid motors. The solid fuel material is a hydroxyl-terminated polybutadiene similar to the rubber used in automobile tires. Gaseous oxygen and liquid oxygen will be used as propellant oxidizers. Gaseous nitrogen will be used for liquid oxygen pressurization.

Air emissions from the triethylaluminum ignitor are minimal. There facility plans to store 5 pounds of liquid triethylaluminum (TEAL). TEAL is a clear, colorless, pyrophoric liquid that is considered a hazardous material. A TEAL reaction with air produces aluminum oxide, steam, carbon oxides, and nitrous oxides and does not produce any toxic emissions. A TEAL reaction with gaseous oxygen/HTPB produces aluminum oxide, steam, and carbon oxides and does not produce any toxic emissions.

Proper safety precautions, as outlined in the TEAL Material Safety Data Sheet, and relief systems will be designed to ensure worker safety and protection. AMROC has safely used TEAL for over 8 years as a hybrid rocket motor ignitor for its 10K hybrid motors. NASA has previously used TEAL as an ignitor on the F-1 liquid rocket engine and General Dynamics currently uses TEAL as the ignitor on the Atlas M-5 liquid engine.

4.9 Radioactive Materials and Nonionizing Radiation

No radioactive materials or nonionizing radiation will be used or released during the CTF hybrid rocket motor operations.

4.10 Noise

There will be minor impacts due to the noise levels generated during the BR and 10K motor tests. The estimated noise levels are similar in magnitude to solid and liquid rocket motors of the same size and thrust class. The noise levels are based on analytical models and actual acoustic measurements obtained during AMROC's hybrid motor tests at Phillips Laboratory, Edwards AFB. The maximum predicted noise level for the BR motor is 71 dB at 5,000 ft from the CTF facility. The maximum predicted noise level for the 10K motor is 88 dB at 5,000 ft. from the CTF facility. The noise duration is very short since the planned duration of the BR tests are 20 seconds and the duration of the 10K tests are 45 seconds. Due to the infrequent and short duration of the test schedules, the noise impacts on the local environment are expected to be minor.

4.11 Land Use Effects

There are no land use effects since the existing CTF facility will be used for the hybrid motor testing operations.

4.12 Socioeconomic Impacts

The proposed activity will employ about 4-6 people from SSC during the CTF facility upgrade. A team consisting of about four SSC and two AMROC people will be involved in the testing operations. The current employment at SSC is about 4,000 people. No new permanent employees will be used during any operations. Since the required team is very small, there will be a negligible socioeconomic impact on SSC.

4.13 Archaeological and Historical Resources

AMROC and SSC plan to use the existing CTF and to modify some test equipment on the site. No activities are planned that would disturb or impact the land, historical or archaeological resources.

4.14 Resource Use

The operations will use the utilities (i.e. electrical power, potable water and telephone service) and fluids (i.e. gaseous nitrogen, gaseous oxygen and liquid oxygen) commonly used during CTF operations. Although the supply of these items are readily available at SSC, the anticipated demand relative to the high volume usage at other SSC test facilities is expected to be minor.

4.15 Accidents and Safety Issues

Due to the benign nature of BR and 10K hybrid rocket motors, standard industrial safety procedures are sufficient to ensure safe and successful test operations. Unlike solid rocket motors, hybrids do not require any special handling or safeguards during shipping, handling or test operations. The discussion in Section 3.1 describes some of the inherent safety features of hybrid rocket motors.

Although the hybrid fuel is non-explosive and since the hybrid combustion chamber is a pressure vessel, there is always the possibility of motor case structural failure due to hot combustion gases creating a leak path in the motor case. However, using steel cases with high margins of safety for the BR and 10K motor test articles will ensure that the probability of case structural failure remains low. If a combustion chamber leak occurs during the test, as evidenced by visible smoke, the motor operations can be terminated by simply closing the main oxidizer valve and stopping the flow of oxidizer (i.e. gaseous oxygen or liquid oxygen) to the combustion chamber.

AMROC is the only company with extensive experience in the development and test of hybrid rocket motors. As with any development program, AMROC has had its share of successes and failures. Throughout all of our motor test operations there have been no major personnel accidents and there has been only minimal damage to test equipment during test mishap. The only air emissions possible during a test mishap are gaseous oxygen, vaporized liquid oxygen or the hybrid combustion gases described in Section 4.2 AMROC is proud or our safety record during all of our hybrid motor development and test activities since the company was founded in 1985.

AMROC has a well established Safety Program at all of our Ventura, Vandenberg AFB and Edwards AFB facilities as shown in References 3, 12, and 13. We plan to work closely with the SSC team to develop a safety plan and test procedures that ensure all Local, State, Federal and NASA safety regulations are satisfied; and that all operations are conducted in a safe and coordinated manner.

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