

# LOAN DOCUMENT

|                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                        |                |               |  |      |      |      |      |             |  |               |  |    |  |               |  |                    |  |              |                             |     |  |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|----------------|---------------|--|------|------|------|------|-------------|--|---------------|--|----|--|---------------|--|--------------------|--|--------------|-----------------------------|-----|--|
| DTIC ACCESSION NUMBER                                                                                                                                                                                                                                                                                                                                                                                                                                | PHOTOGRAPH THIS SHEET                                                                                                  | INVENTORY<br>0 |               |  |      |      |      |      |             |  |               |  |    |  |               |  |                    |  |              |                             |     |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                      | LEVEL                                                                                                                  |                |               |  |      |      |      |      |             |  |               |  |    |  |               |  |                    |  |              |                             |     |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Development of a H <sub>2</sub> O <sub>2</sub> Mudcrice Thruster<br>for Target Applications<br>DOCUMENT IDENTIFICATION |                |               |  |      |      |      |      |             |  |               |  |    |  |               |  |                    |  |              |                             |     |  |
| DISTRIBUTION STATEMENT A<br>Approved for Public Release<br>Distribution Unlimited                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                        |                |               |  |      |      |      |      |             |  |               |  |    |  |               |  |                    |  |              |                             |     |  |
| DISTRIBUTION STATEMENT                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                        |                |               |  |      |      |      |      |             |  |               |  |    |  |               |  |                    |  |              |                             |     |  |
| <table border="1"><tr><td colspan="2">ACCESSION FOR</td></tr><tr><td>NTIS</td><td>GRAM</td></tr><tr><td>DTIC</td><td>TRAC</td></tr><tr><td>UNANNOUNCED</td><td></td></tr><tr><td>JUSTIFICATION</td><td></td></tr><tr><td colspan="2">BY</td></tr><tr><td colspan="2">DISTRIBUTION/</td></tr><tr><td colspan="2">AVAILABILITY CODES</td></tr><tr><td>DISTRIBUTION</td><td>AVAILABILITY AND/OR SPECIAL</td></tr><tr><td>A-1</td><td></td></tr></table> |                                                                                                                        |                | ACCESSION FOR |  | NTIS | GRAM | DTIC | TRAC | UNANNOUNCED |  | JUSTIFICATION |  | BY |  | DISTRIBUTION/ |  | AVAILABILITY CODES |  | DISTRIBUTION | AVAILABILITY AND/OR SPECIAL | A-1 |  |
| ACCESSION FOR                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                        |                |               |  |      |      |      |      |             |  |               |  |    |  |               |  |                    |  |              |                             |     |  |
| NTIS                                                                                                                                                                                                                                                                                                                                                                                                                                                 | GRAM                                                                                                                   |                |               |  |      |      |      |      |             |  |               |  |    |  |               |  |                    |  |              |                             |     |  |
| DTIC                                                                                                                                                                                                                                                                                                                                                                                                                                                 | TRAC                                                                                                                   |                |               |  |      |      |      |      |             |  |               |  |    |  |               |  |                    |  |              |                             |     |  |
| UNANNOUNCED                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                        |                |               |  |      |      |      |      |             |  |               |  |    |  |               |  |                    |  |              |                             |     |  |
| JUSTIFICATION                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                        |                |               |  |      |      |      |      |             |  |               |  |    |  |               |  |                    |  |              |                             |     |  |
| BY                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                        |                |               |  |      |      |      |      |             |  |               |  |    |  |               |  |                    |  |              |                             |     |  |
| DISTRIBUTION/                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                        |                |               |  |      |      |      |      |             |  |               |  |    |  |               |  |                    |  |              |                             |     |  |
| AVAILABILITY CODES                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                        |                |               |  |      |      |      |      |             |  |               |  |    |  |               |  |                    |  |              |                             |     |  |
| DISTRIBUTION                                                                                                                                                                                                                                                                                                                                                                                                                                         | AVAILABILITY AND/OR SPECIAL                                                                                            |                |               |  |      |      |      |      |             |  |               |  |    |  |               |  |                    |  |              |                             |     |  |
| A-1                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                        |                |               |  |      |      |      |      |             |  |               |  |    |  |               |  |                    |  |              |                             |     |  |
| DISTRIBUTION STAMP                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                        |                |               |  |      |      |      |      |             |  |               |  |    |  |               |  |                    |  |              |                             |     |  |
| DATE RECEIVED IN DTIC                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                        |                |               |  |      |      |      |      |             |  |               |  |    |  |               |  |                    |  |              |                             |     |  |
| 20000814 219                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                        |                |               |  |      |      |      |      |             |  |               |  |    |  |               |  |                    |  |              |                             |     |  |
| REGISTERED OR CERTIFIED NUMBER                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                        |                |               |  |      |      |      |      |             |  |               |  |    |  |               |  |                    |  |              |                             |     |  |
| DATE RETURNED                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                        |                |               |  |      |      |      |      |             |  |               |  |    |  |               |  |                    |  |              |                             |     |  |
| DATE ACCESSIONED                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                        |                |               |  |      |      |      |      |             |  |               |  |    |  |               |  |                    |  |              |                             |     |  |

H  
A  
N  
D  
L  
E  
  
W  
I  
T  
H  
  
C  
A  
R  
E



UNCLASSIFIED

# **Sandia National Laboratories**

---

## **Flight Test - Session 12**

# **Development of a $H_2O_2$ Guidance Thruster for Target Applications**

Mark C. Grubelich and William R. Escapule, Sandia National Laboratories,  
Albuquerque, NM.

*Approved for Public Release;  
Distribution is Unlimited.*

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000



UNCLASSIFIED





UNCLASSIFIED

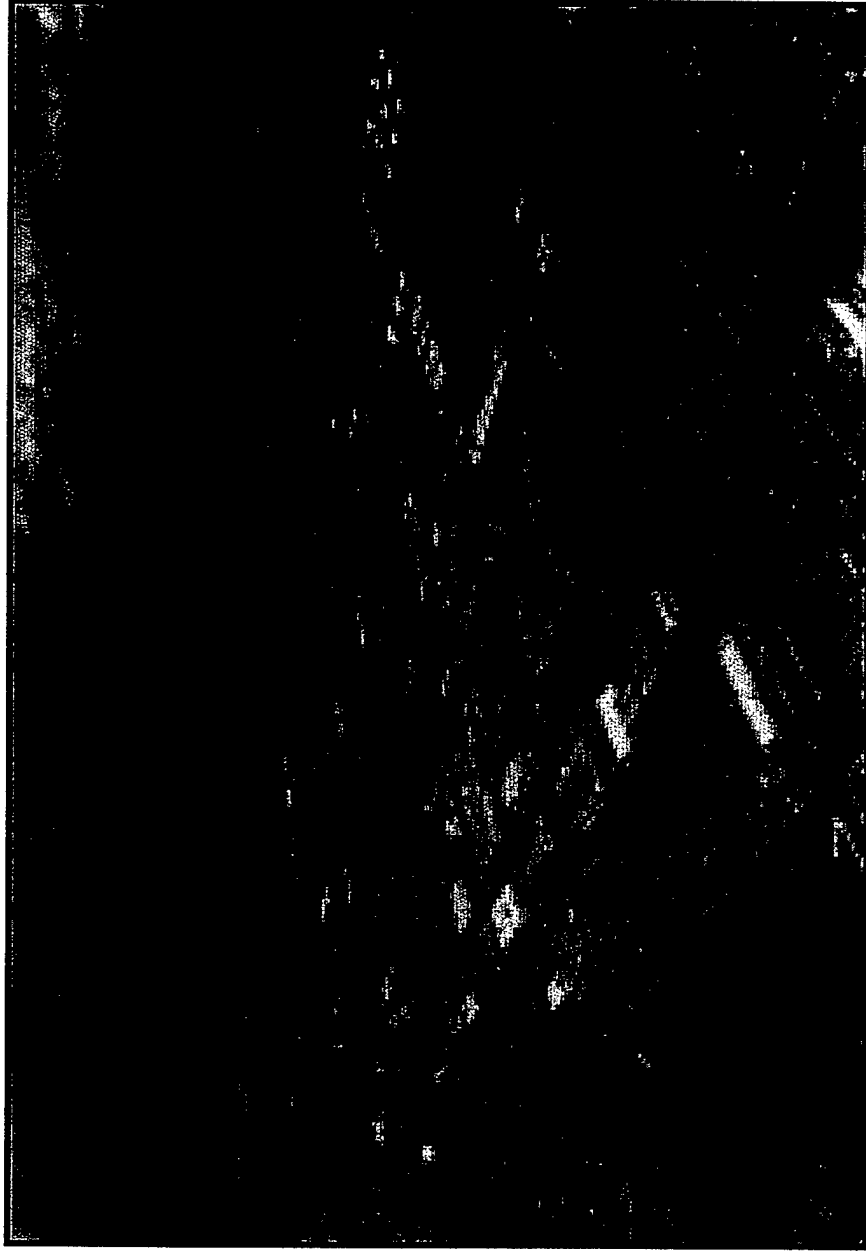
# Sandia National Laboratories

---

Sandia is government-owned, contractor-operated multi-disciplinary laboratory. Federal funding and direction are provide by the U.S. Department of Energy. The main site is co-located with Kirtland AFB in Albuquerque, New Mexico.

Over 7500 full-time staff are employed at Sandia with approximately 75% of the scientists and engineers holding advanced degrees in their technical disciplines.

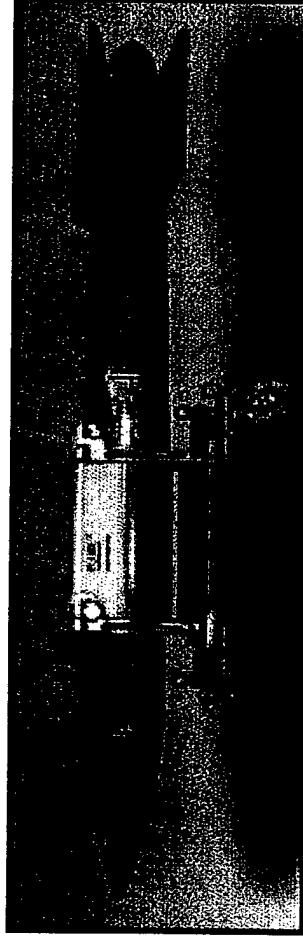
An extensive number of facilities are available to design, fabricate and test aerospace components and systems



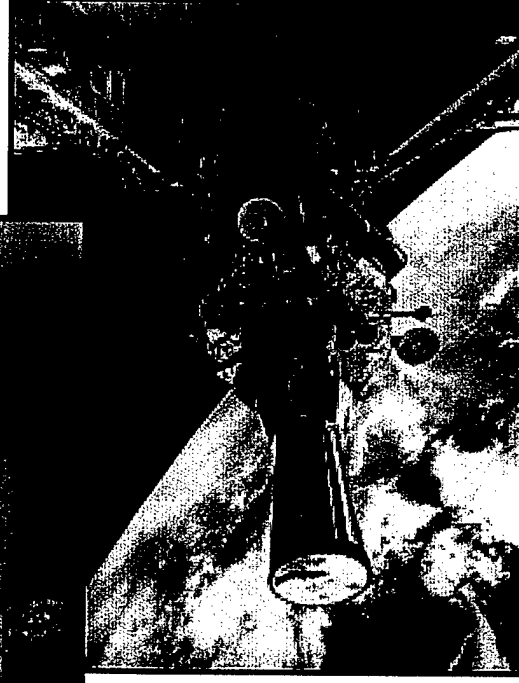
UNCLASSIFIED

UNCLASSIFIED

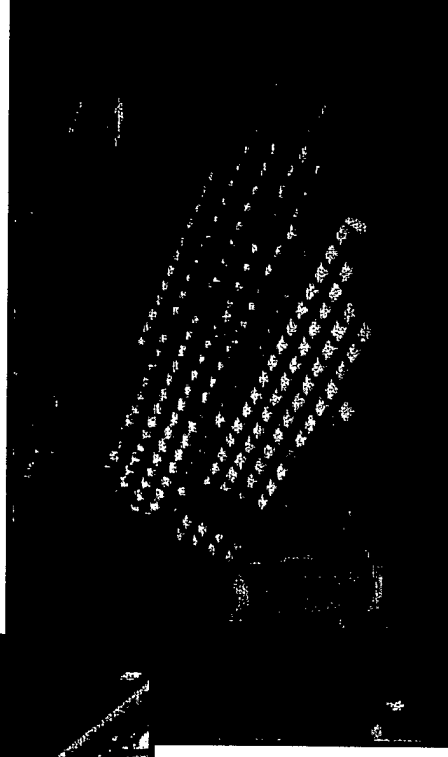
## **Exceptional Service in the National Interest**



Sandia's primary mission is stewardship of the nation's nuclear weapons stockpile.



Sandia also executes work for other federal agencies and industry when it is complementary to our primary mission and it is in the nation's interest.



UNCLASSIFIED





UNCLASSIFIED

# Aerospace Systems Development Center

## Special capabilities

Pre-prototyping  
Hypersonic vehicles  
Reentry systems  
ICBM payloads  
Sounding rockets/STARS  
Advanced munitions  
Special projects  
Rehabilitation Engr & Assistive Technology

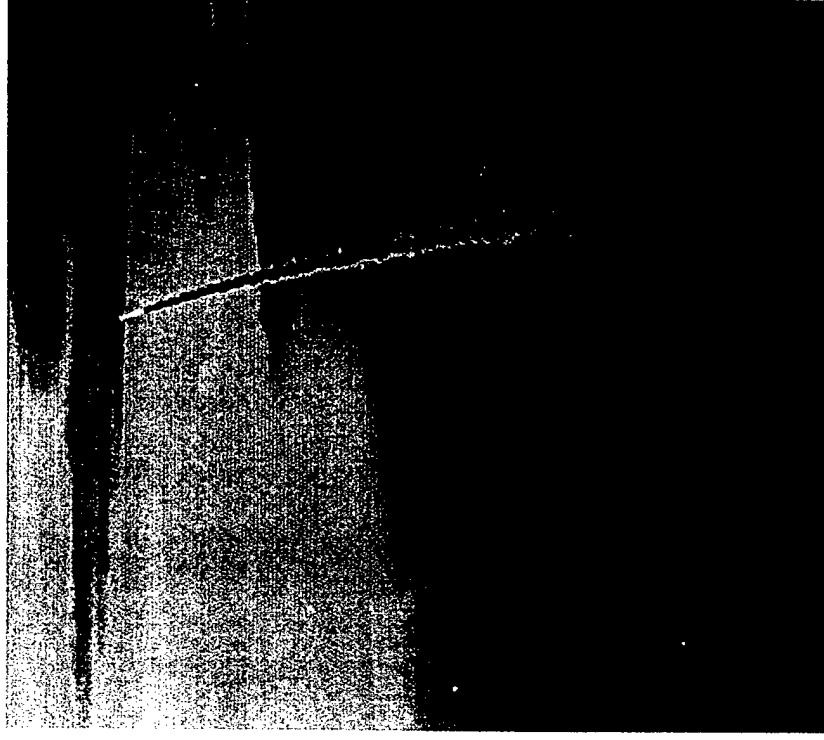
## Expertise

Systems Integration  
Mission planning  
Mechanical/electrical design  
One-of-a-kind fabrication  
Flight qualification  
Telemetry & instrumentation  
Field operations  
Data collection, reduction & analysis

## Customers

BMDO, USASMDC, NASA, DARPA, DTRA,  
USAF/AFRL, USN/SSPO, SNL/DP, NIH, VA

SNL Payload on Minuteman, launched from VAFB



Develop & integrate  
advanced aerospace  
systems



Respond promptly to  
customers needs



Execute full-scale, high risk  
technology demonstrations



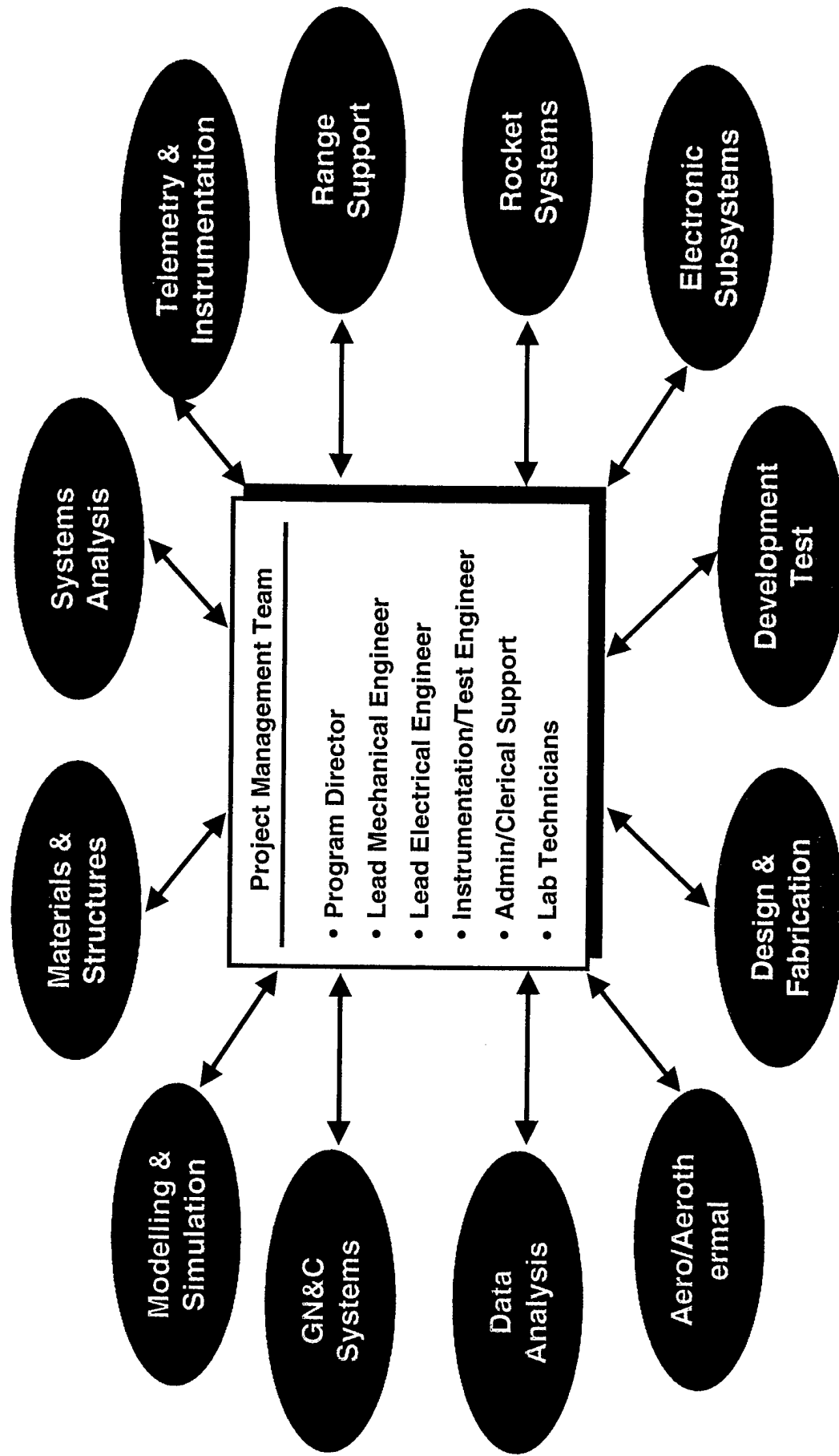
Sandia  
National  
Laboratories

UNCLASSIFIED



UNCLASSIFIED

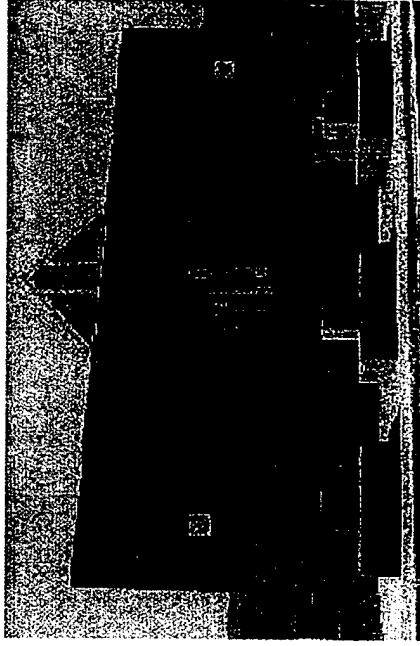
# Aerospace Systems Engineering Capability



UNCLASSIFIED

UNCLASSIFIED

# Energetic Materials Research



Main Laboratory



Control Room

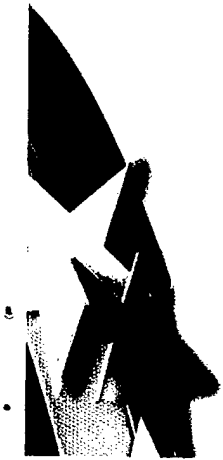


Test Cell

*Sandia has the highly skilled staff and a state-of-the-art facility required to successfully conduct research, development and testing of energetic materials. For more information, visit our web site at <http://www.sandia.gov/explosive>.*

UNCLASSIFIED



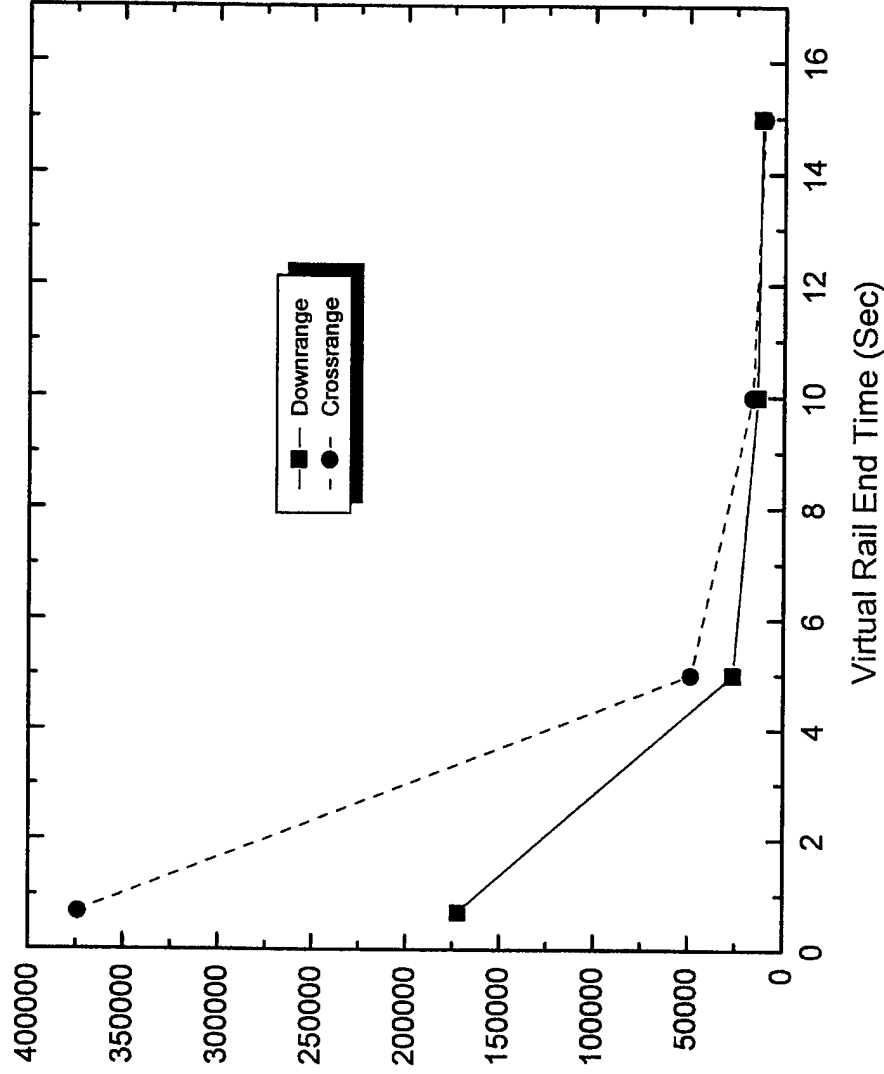


# UNCLASSIFIED

## Virtual Rail Concept

### Initiated Sandia Interest in $H_2O_2$

- Virtual Rail Concept
  - Dispersion reduction by controlling vehicle attitude after end of actual rail length
- Vehicle attitude controlled by combination of Sandia's spinning NG&C approach and Hydrogen Peroxide engines
- Initial analyses indicate that 75-85% of dispersion can be eliminated through effective control during first 10 seconds of flight

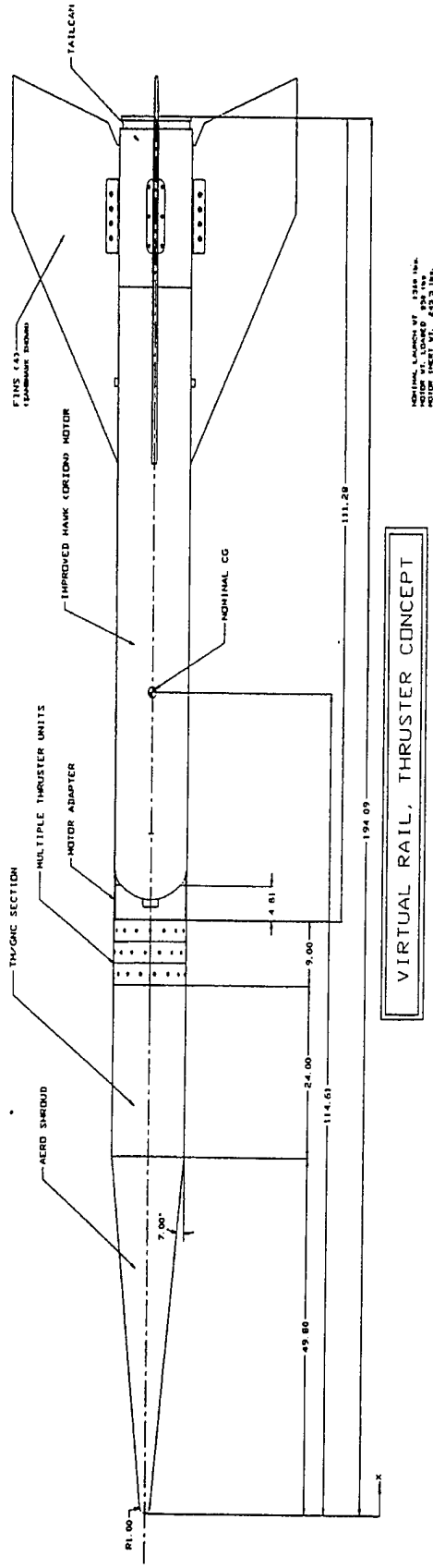


UNCLASSIFIED



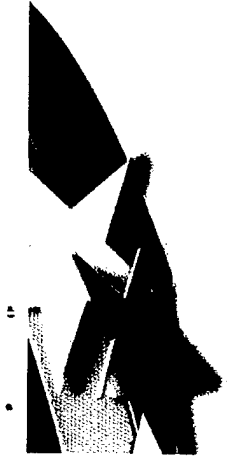
UNCLASSIFIED

# Virtual Rail System Concept



Rocket engines fire as the flight system spins to produce a controlling moment to reduce dispersions.

UNCLASSIFIED



UNCLASSIFIED

# **Hydrogen Peroxide**

---

## **Why Use It?**

- Long history
- Flexible use (monopropellant, oxidizer)
- Good density impulse
- Low (adjustable) combustion temperature
- “Non” toxic, Non-carcinogenic
- Clean exhaust (environmentally friendly, hardware friendly)

UNCLASSIFIED



UNCLASSIFIED

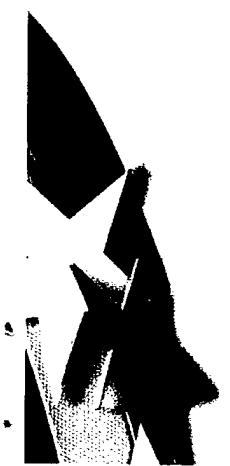
# **Hydrogen Peroxide**

---

**What is it?**

- $\text{H}_2\text{O}_2 \rightarrow \text{H}_2\text{O} + \frac{1}{2}\text{O}_2 + \text{Energy}$ 
  - 3% pharmaceutical
  - 31% semiconductor
  - 50% waste-water
  - 60% oxidizer/IC engine
  - 70% oxidizer/monopropellant rocket engine
  - 90+% propulsion grade

UNCLASSIFIED



UNCLASSIFIED

# **Hydrogen Peroxide**

## **The Re-discovered Propellant**

### **• History**

- Reported 1818 by Thenard (government-subsidized research)
- 1933 Torpedo propulsion, US Navy
- 1934 60% used for underwater propulsion, Germany (type 26 boat, 900 tons displacement, 90 tons Hydrogen Peroxide, 24k, 6hr, 7500hp) V-1, V-2, Me 163, RATO units
- 1952/3 Sprite, Super Sprite Dehavilland Engine Co., England
- 1954 225 ft “Explorer”, Great Britain (nicknamed the “Exploder”)
- Redstone, Mercury, Scout,...LLS, SYNCOM, COMSAT, X-15....?1970 to present Hydrazine takes over...

UNCLASSIFIED

UNCLASSIFIED

# 1984 Olympics

---

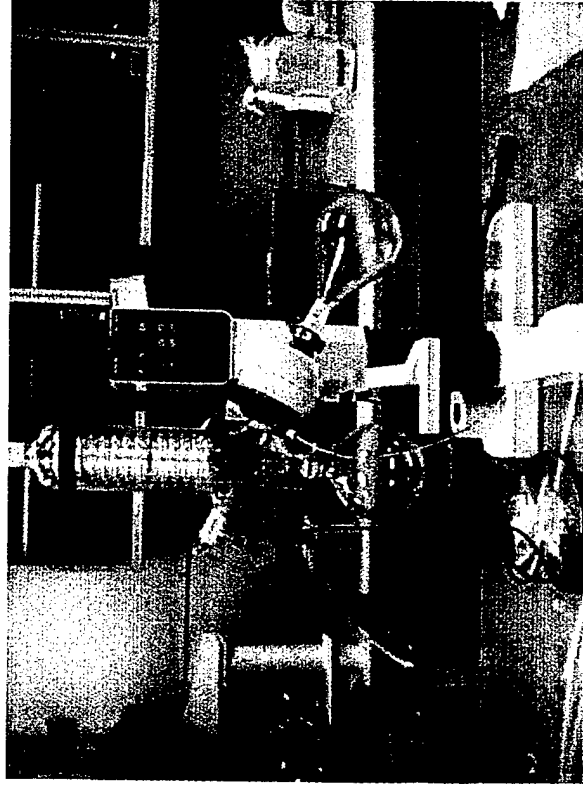


UNCLASSIFIED

UNCLASSIFIED

## Elements of Sandia's H<sub>2</sub>O<sub>2</sub> Program

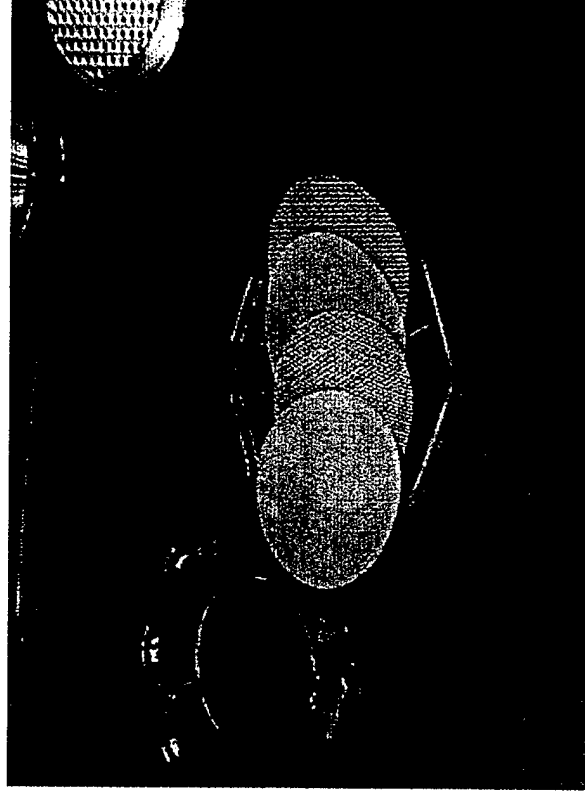
---



Hydrogen peroxide was not available in the high concentrations required. Sandia purchased hardware and developed processes to produce and handle >95% pure H<sub>2</sub>O<sub>2</sub>.

Sandia examined a variety of different catalyst materials and coating techniques.

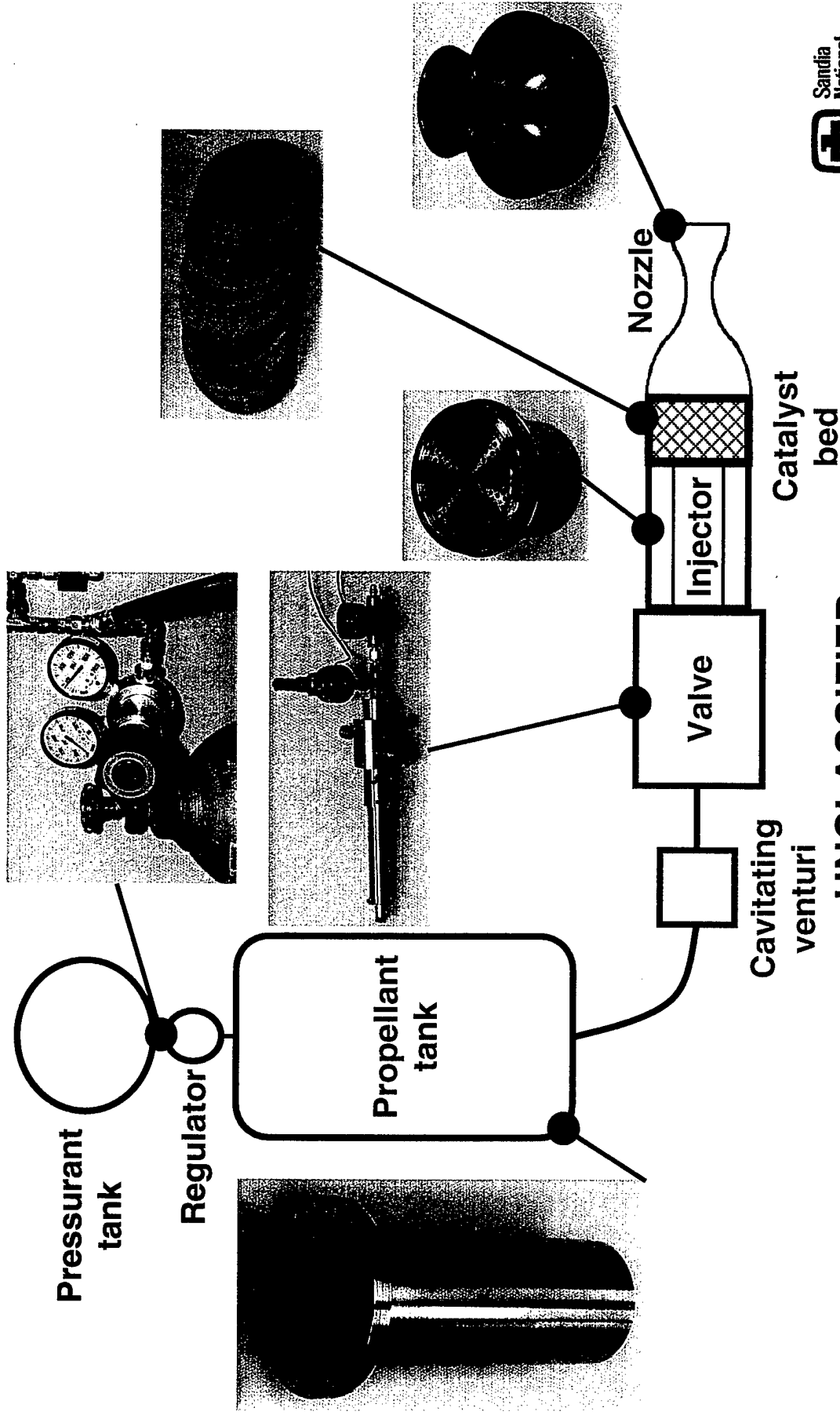
Catalyst packs were developed in house at the ECF and AML



UNCLASSIFIED

UNCLASSIFIED

# Monopropellant Rocket Engine



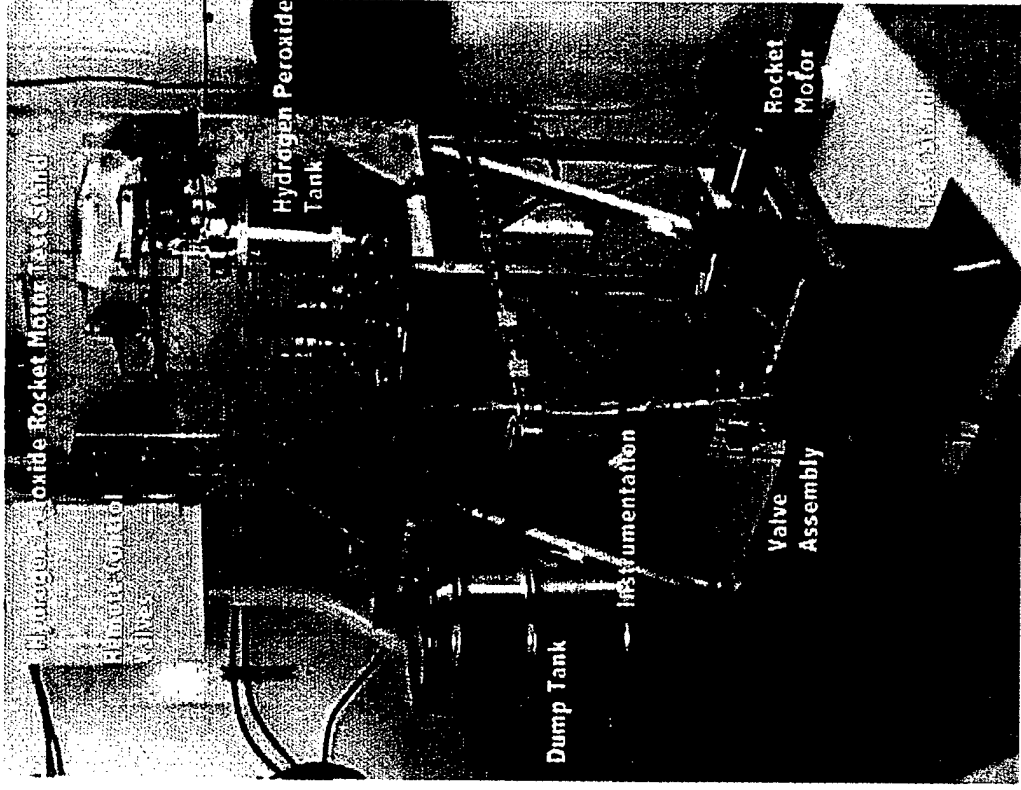
UNCLASSIFIED

UNCLASSIFIED

# H<sub>2</sub>O<sub>2</sub> Test Setup

A control room and test cell were configured in the ECF to conduct the development tests.

This arrangement was used to perform several successful firings of the H<sub>2</sub>O<sub>2</sub> development engine.



UNCLASSIFIED



UNCLASSIFIED

# Development Test Photos

---



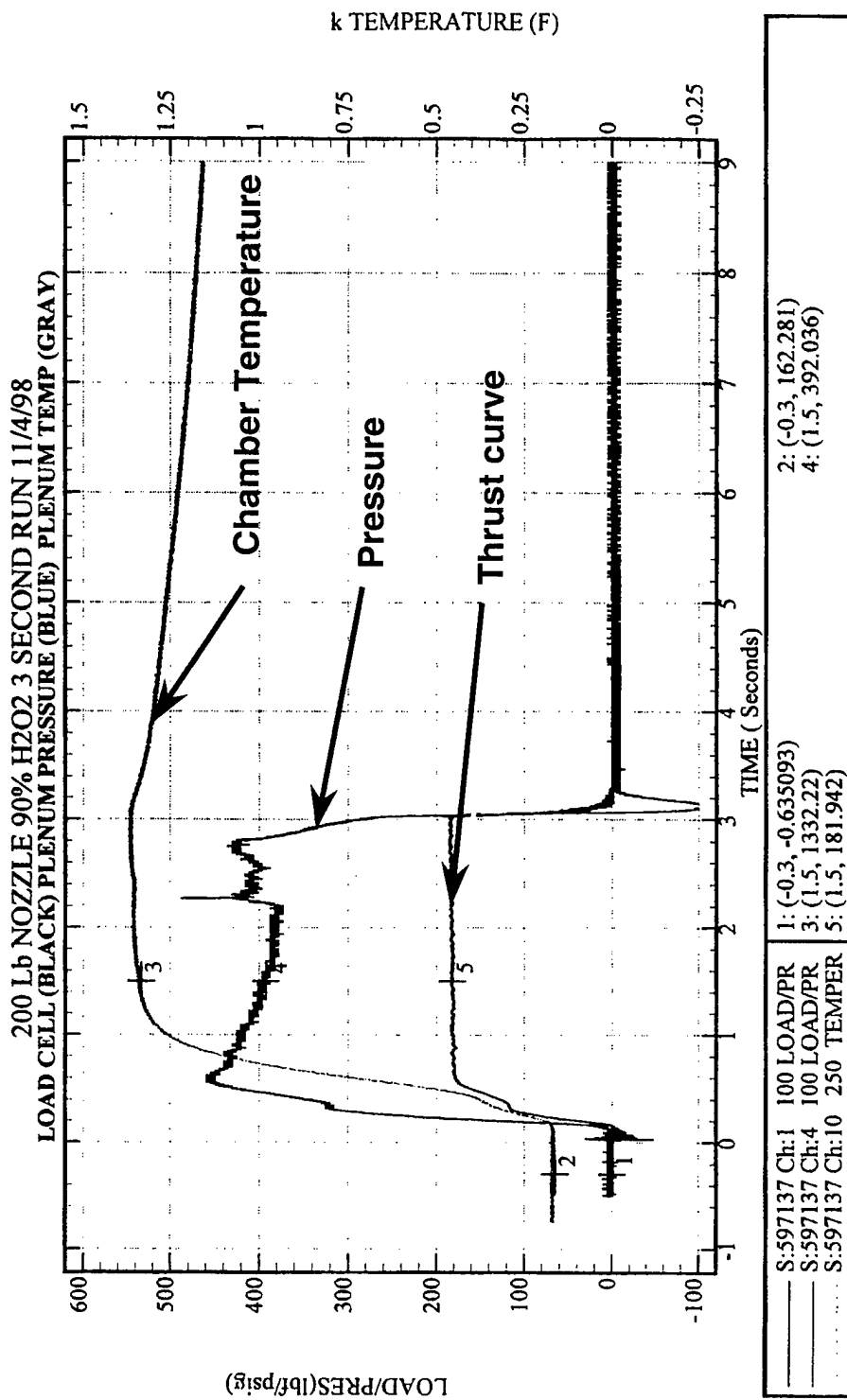
Video coverage of the  $H_2O_2$  development tests captured the initial startup and steady state operating phase. These short duration test runs (1-3 seconds) demonstrated the ability to develop required force-time duration for our applications.

UNCLASSIFIED

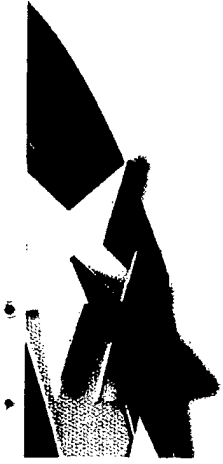


# UNCLASSIFIED H<sub>2</sub>O<sub>2</sub> Development Testing Results (12/98)

- Results from the recent development testing were very favorable
- Validated design and analysis predictions
- Demonstrated a capability to produce and handle concentrated H<sub>2</sub>O<sub>2</sub>
- Developed testing approaches, facilities and processes



UNCLASSIFIED



UNCLASSIFIED

# **Accomplishments**

---

- **Developed**
  - **safety procedures to handle material**
  - **hardware and process to distill 31% to 90+%**
  - **high speed control valve**
  - **catalyst pack**
  - **rocket engine**
  - **test stand**

**In house liquid propellant capability in 6 months!**

UNCLASSIFIED





UNCLASSIFIED

## What did we learn?

---

- Simple vacuum distillation works well (liters/day)
- Clean / passivated hardware is imperative!
- Catalyst technology was somewhere between alchemy and sorcery
- Silver coatings on stainless steel screens work
- Solid silver screens work without Samarium Oxide coating
- High speed control valve works (20 ms response time)
- Semiconductor grade  $H_2O_2$  material cleanest ever available
- All historical accidents attributable to organic contamination or gross mishandling

UNCLASSIFIED



UNCLASSIFIED

# **The Future of Hydrogen Peroxide**

- Mars sample return mission
- Hydrazine replacement  
(LM “Skunk Works” U2 gas generator)
- Chem/Bio agent decontamination
- Future Sandia flights
- SNL nanopropulsion

**Use Your Imagination Now That  
The Capability Exists Again!**

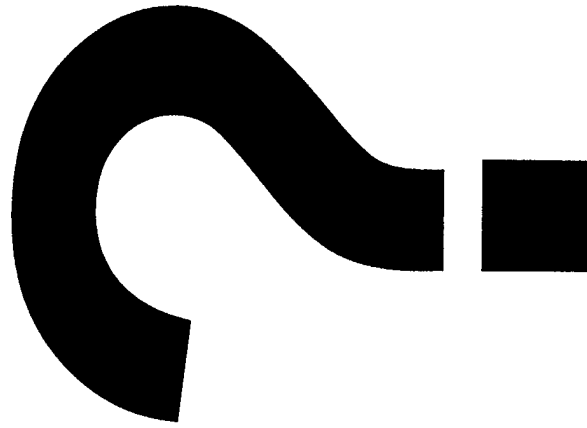
UNCLASSIFIED





UNCLASSIFIED  
**Discussion**

---



UNCLASSIFIED