Thiokol Propulsion

NARC Rayon Replacement Program

Domsjö Fabriker AB Introduction

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ATK
ALLIANT TECHSYSTEMS

Introduction To Thiokol

1926 - Dr. Joseph C. Patrick attempts to make antifreeze, but instead makes the first manmade rubber. He calls it "Thiokol" combining the Greek work *theion* (sulfur) and *kolla* (glue)

1929 - Thiokol Corporation is formed

1957 - Thiokol buys an isolated tract of land near Promontory, Utah for a plant to manufacture and test large solid rocket motors

1959 - First Air Force Minuteman heavy weigh case is static test fire

1965 - Joint venture with Hercules to develop propulsion for Poseidon (C3) for the Navy. This eventually led to contracts for Trident I (C4 and D5)

1974 - NASA's Space Shuttle solid rocket motor development contract is awarded to Thiokol

1981- The first Space Shuttle (STS-1), *Columbia*, is launched using Thiokol solid rocket motors

1987- The Redesigned Solid Rocket Motor (RSRM) is successfully static fired

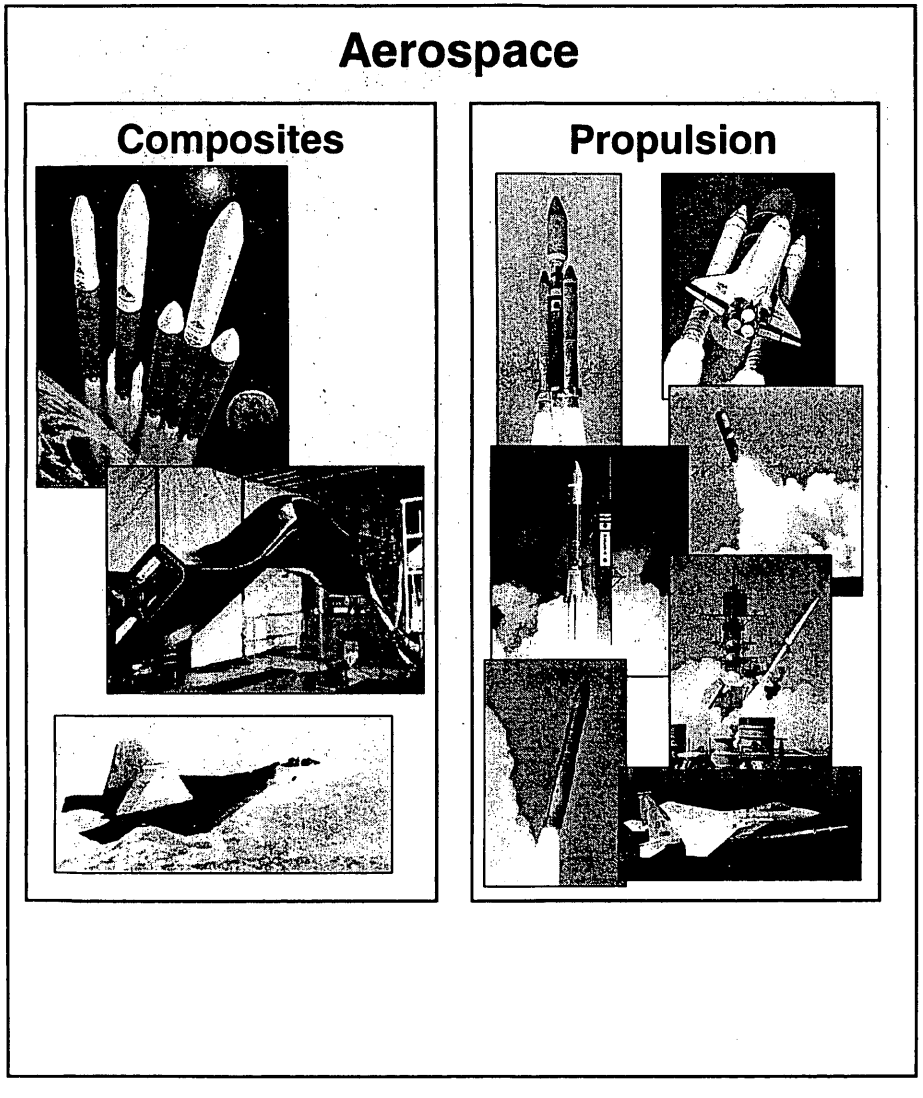
1988- *Discovery* is launched using Thiokol's RSRM (STS-26) - return to flight

1997- Bob Crippen comes aboard as a president of the newly formed Aerospace Group – Cordant Technologies

2000 - Cordant Technologies purchased by Alcoa Aluminum

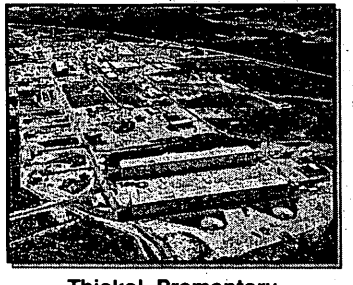
2001 - Thiokol sold to ATK – Sell finalized on 13 April

ATK's Lanes of Excellence



- Growth opportunity
- Expanded capability
- Long-term business
- 100% mission success

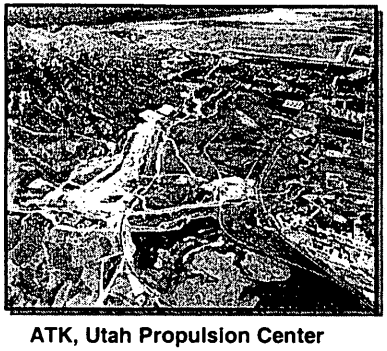
Facility Locations



Thiokol, Promontory

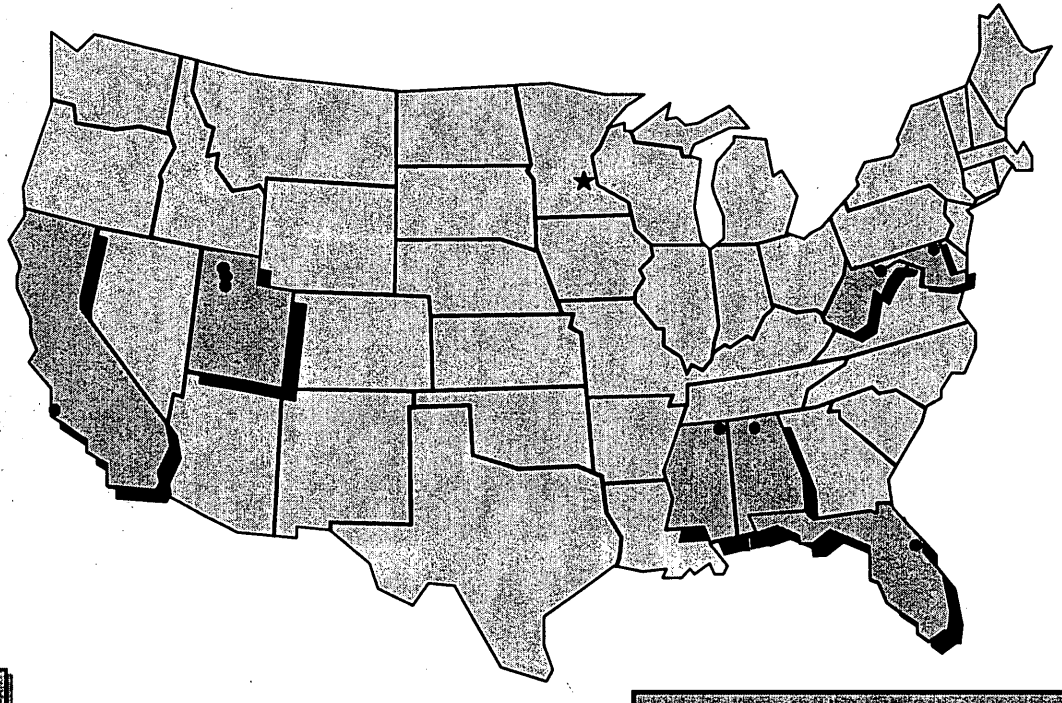
ATK, Utah Composites Center

Thiokol, Clearfield Operations



ATK, Utah Propulsion Center

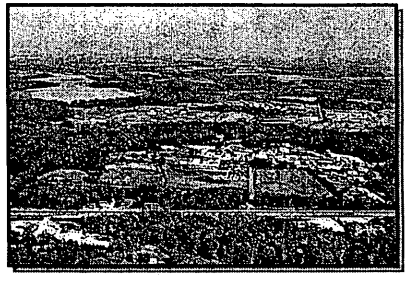
ATK, Space Structures



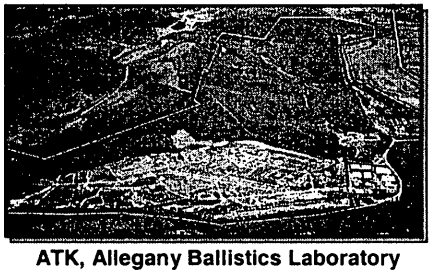
ATK, Southern Composites Center

Other Sites

- Thiokol Composites & Resins (TCR), Ogden
- Marshall Space Flight Center (MSFC), Huntsville
- Kennedy Space Center (KSC)/ Cape Canaveral Air Station (CCAS)
- Vandenberg Air Force Base (VAFB)
- International sites – Russia, Ukraine

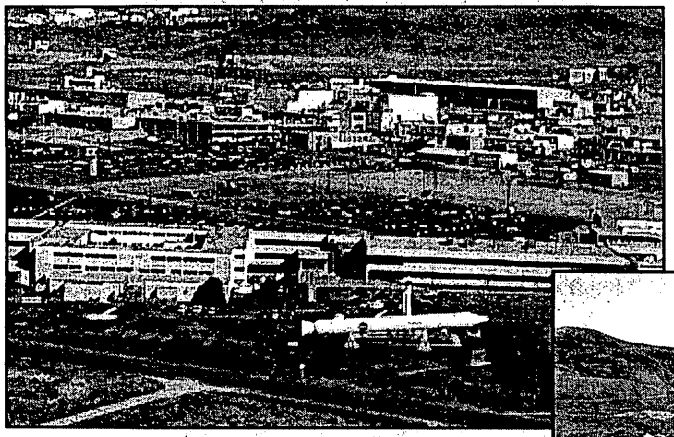


Thiokol, Elkton

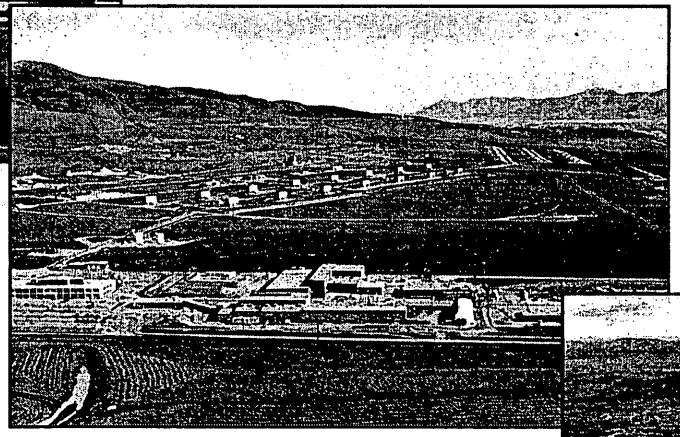


ATK, Allegany Ballistics Laboratory

Northern Utah Facilities



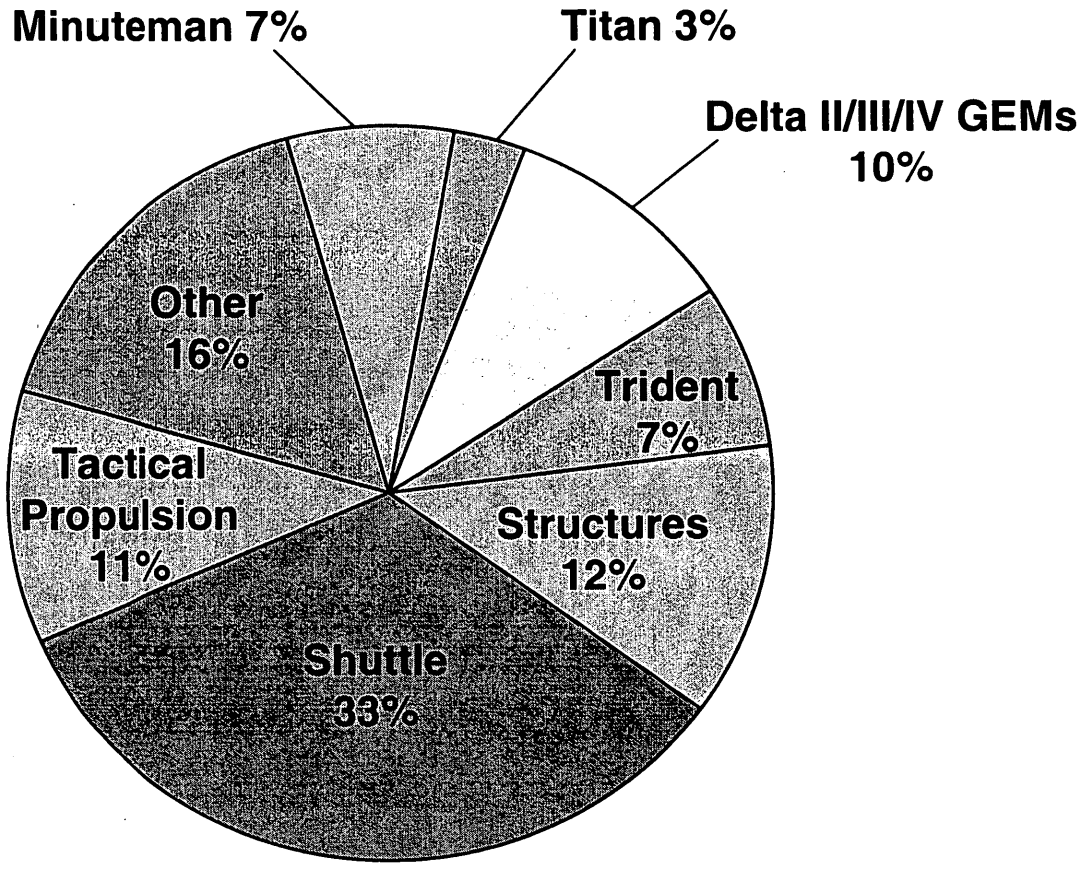
Space Operations

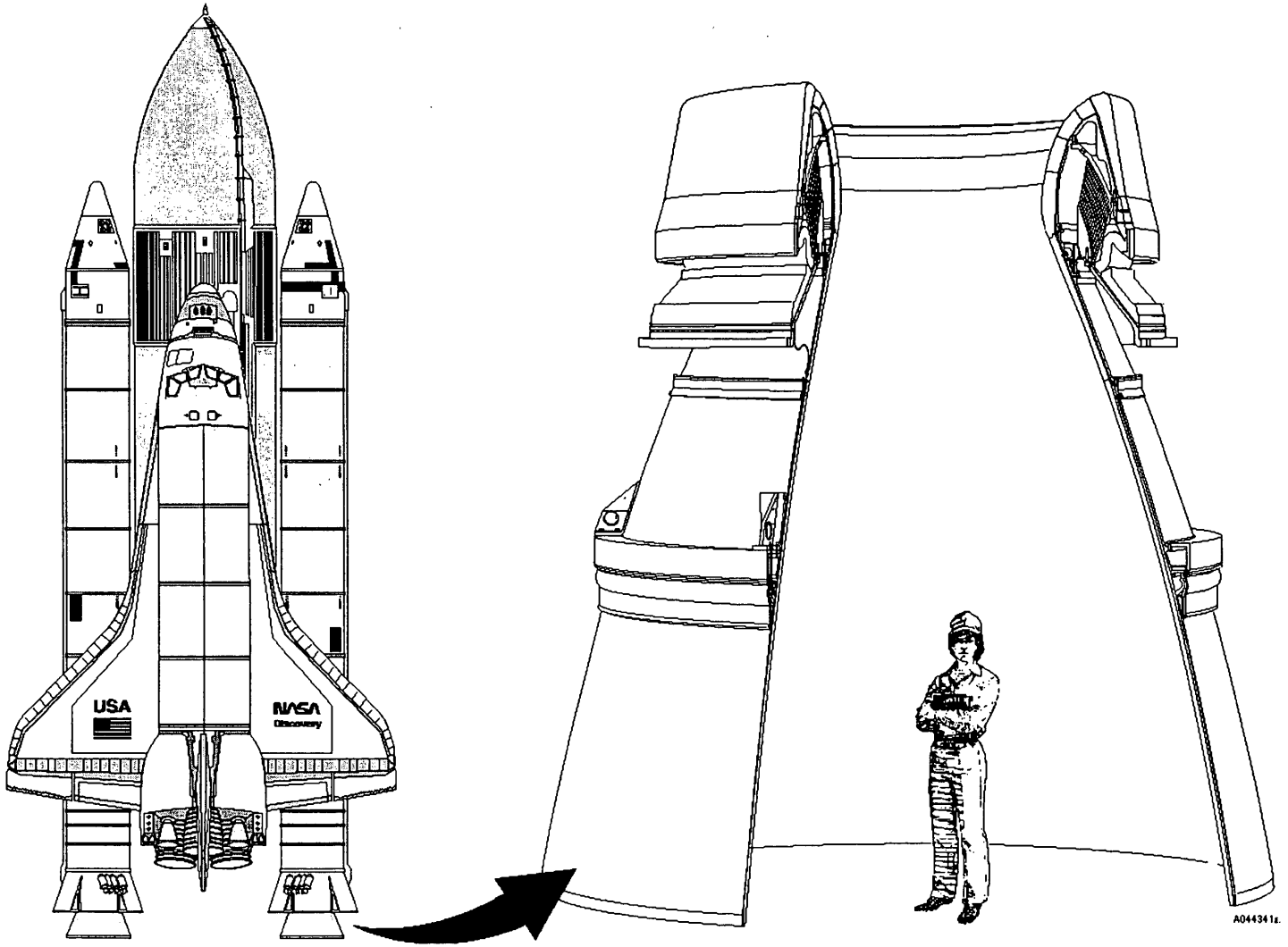


Defense and
Launch Vehicles

Test

ATK Aerospace Program Summary




USA
NASA
Discovery
A044341a

RSRM Facts
(Reusable Solid Rocket Motor)

- During the first two minutes of flight, the twin RSRMs:
  - produce 36,000,000 horsepower (26,856,000 kilowatts) (as much as 102,600 corvettes)(134,328 Volvo S80's)
  - burn 2,215,000 pounds (1,000,000 kg) of propellant – approximately 10 tons (8400 kg) per second
  - boosts the shuttle to an altitude of 30 miles (48 km)
  - Shuttle reaches a top speed of 3094 miles/hr (5000 km/hr)
- The exhaust gas reaches a temperature of 6000°F (3300°C) (approx. 2/3 the temperature of the sun's surface).
- Each RSRM develops the equivalent power to service 630 homes for one month.
- Thiokol makes 110,000 quality control inspections on each flight set.
- 41 Metric Tons of dissolving pulp are used for each flight.

Background

- **North American Rayon Corporation (NARC) discontinued production of Aerospace Grade Rayon in September 1997 for financial reasons**
  - This rayon is a precursor to carbon cloth phenolic (CCP)
- **NASA purchased a stockpile of NARC rayon prior to the shutdown to support RSRM production through at least 2005**
- **Second rayon vendor to go out of business during Space Shuttle Program**

NARC Rayon Replacement Program Objectives

- Find the best replacement fiber for NARC rayon used in the RSRM nozzle CCP considering
  - Performance
  - Process ability
  - Variability
  - Long term availability
  - Cost
- Incorporate knowledge gained in ASRM, Improved Ablatives Program, Solid Propulsion Integrity Program (SPIP), STS-79 Pocketing Investigation, and Engineering Enhancement Program to reduce CCP material variability and ensure predictable performance
- Goal to stay within existing design envelope
- Preference given to "Off the shelf" materials rather than custom made

RSRM Rayon Replacement Program Plan

Phase I - Candidate Screening
Objective: Evaluate fiber candidates using RSRM baseline processes
Status: Completed in Februay 2000. 21 fiber candidates tested and 12 selected for further evaluation and optimization

Phase IA - Process Optimization Pathfinder
Objective: Better understand the process parameters for the most promising candidates by performing optimization studies
Status: Completed in June 2000. Over 700 process studies were performed. Four types of fibers were selected for further evaluation in Phase II

Phase II - Process Optimization
Objective: Verify the results of Phase IA by evaluating the four most promising fibers under several processing parameters.
Status: Completed in April 2001. 36 candidates tested. Best Enka Candidates progress to Phase III, Lyocell candidates further optimized in Phase IIA

Phase IIA - Lyocell Optimization
Objective: Improve the performance of the lyocell candidates before proceeding with Phase III
Status: Completed in November 2001. 32 Trials tested.

Phase III - Variability Study
Objective: Determine the lot-to-lot and within lot variability of the best candidates. Characterize these four candidates and select the replacement
Status: 4 of 6 Enka lots have completed testing. First NSP Lyocell lot has completed testing, First SGL Lyocell lot in process. Estimated Completion Date: September 2002

Phase IV - Qualification
Objective: Complete characterization of the selected material and demonstrate acceptable perfomance in three full scale static test motors
Status: Scheduled to start in September 2002

Phase I Summary

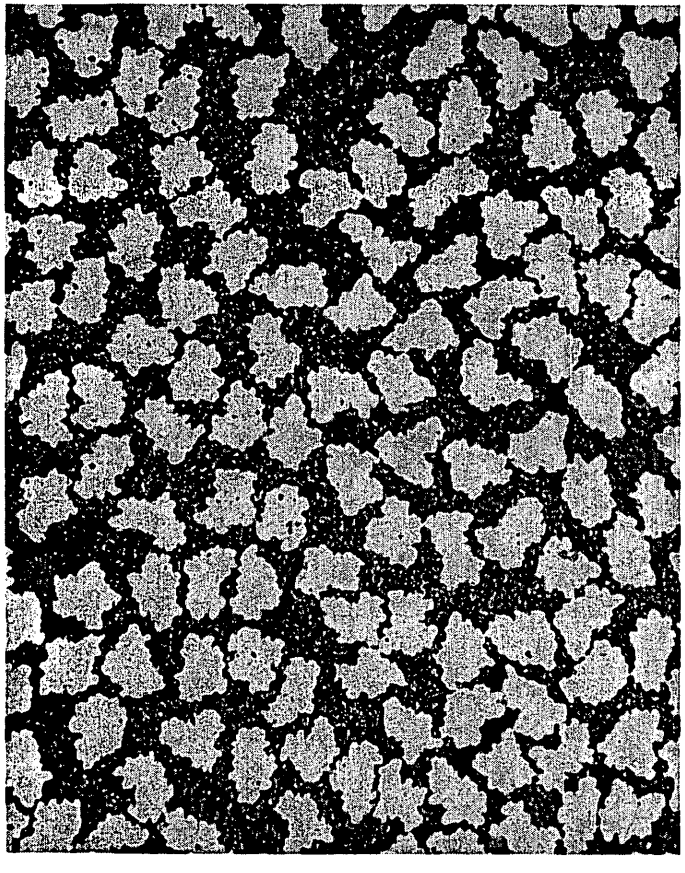
- The objective of Phase I was to screen prospective fiber candidates using baseline RSRM processes
- Twenty-one fibers were tested from the following fiber families
  - Staple rayon
  - Tire cord rayon
  - Continuous filament textile rayon
  - Aerospace grade rayon
  - Staple lyocell
  - Continuous filament lyocell
- The most promising candidates from each fiber family were selected for further evaluation in Phase IA

Phase II Summary

- The objective of Phase II was to demonstrate the acceptable performance of the most promising fibers in conjunction with selected optimized processes

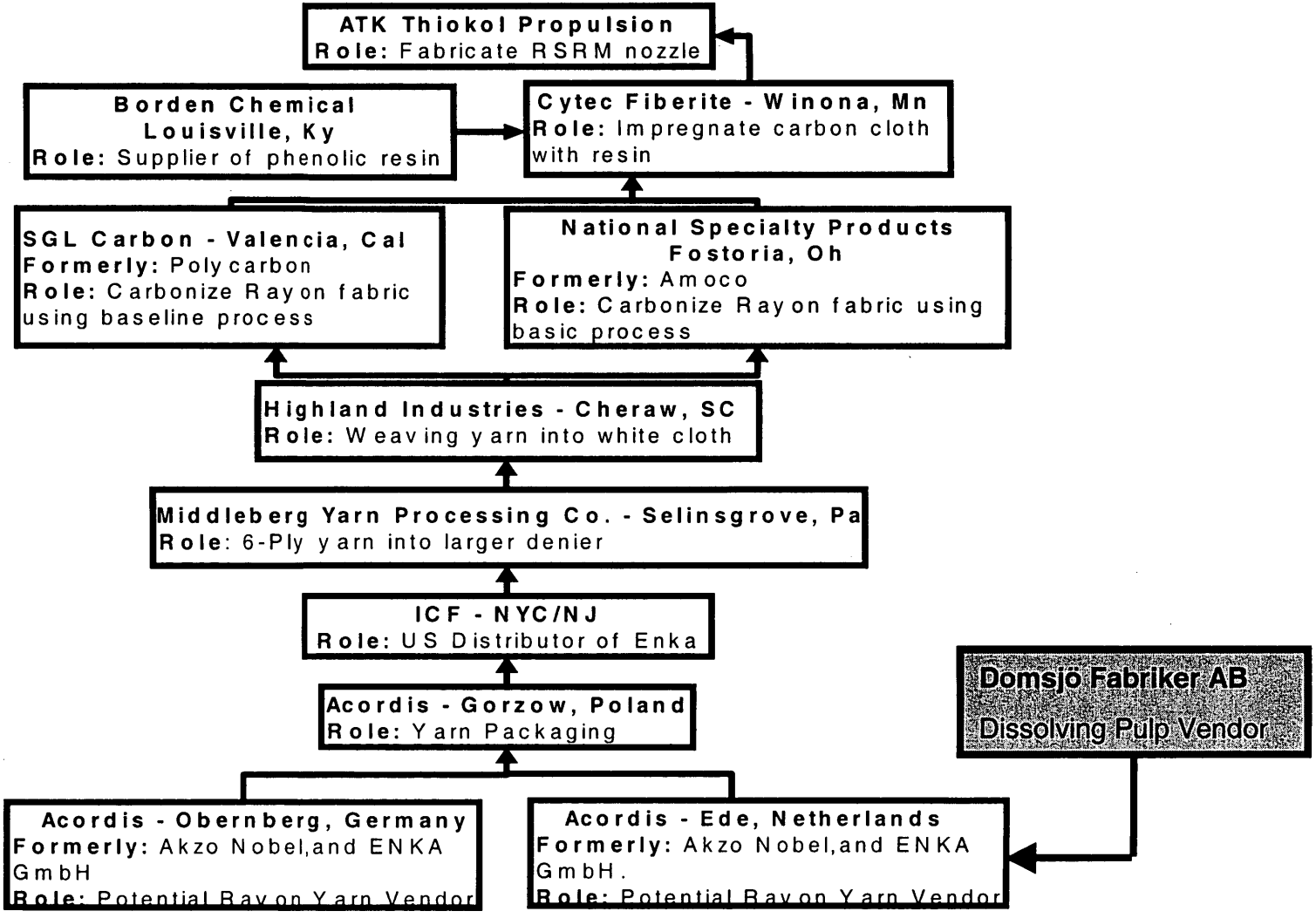
- Acordis Enka textile rayons, carbonized by both SGL Carbon and NSP, were selected for further evaluation in Phase III - Standard NARC processes were selected

N Candidates (Enka Textile Rayon)



- **Manufactured in two Acordis plants (Ede, Netherlands and Obernburg, Germany)**
  - Most Common Use: Textiles (Jacket linings largest single use)
- **Woven by Highland Industries in a 5 Harness Satin pattern**
- **Both SGL Carbon and NSP are using the baseline NARC carbonization process, with minor adjustments**
- **RSRM – evaluating Ede and Obernburg**

Enka Textile Rayon Vendor Summary (Candidate N)



N Candidates (Enka Textile Rayon)

- **Pros**
  - Closest to NARC in process ability, carbon properties and structural performance
- **Cons**
  - Rayon long term availability is questionable
- **Vendor status**
  - The European Commission has refused to give consent for the formation of Newco (merger of Acordis and Lenzing cellulose lines)
  - Effect on the Ede and Obernburg plants unknown at this time

RSRM Summary

- **Two fibers still under consideration**
  - Acordis Enka Textile Rayon
  - Acordis Staple Lyocell
- **Enka Textile Rayon Status**
  - Four of the six lots in Phase III have completed testing
  - The remaining two lots are currently being woven with testing to be completed by mid summer
- **Final candidate selection is scheduled for September 2002**

Rayon Criticality to Space Shuttle Program

- **Manned space flight is inherently very high risk (Astronaut Safety is #1)**
  - Shuttle assets and program costs are very expensive
- **Shuttle Benefits**
  - Hubble/Chandra telescopes - space science breakthroughs
  - International Space Station- space science, earth science, life science
  - Recent earth 3-d mapping - safer navigation systems
- **Shuttle Propulsion Elements require high reliability**
  - Orbiter main engines - Reliability benefits from prelaunch firing
  - RSRM - Reliability is dependent upon consistent materials and processes, and change control

Rayon Criticality (cont.)

- **Rayon is used as basic precursor for RSRM nozzle insulators**
  - Single points of failure (e.g. no redundancy)
  - Less than full understanding of physics behind insulative performance
- **Relatively small thermal safety factors in various regions of the nozzle**
  - Small tolerance for performance variance
- **Safety is dependent upon conformance to material acceptance specifications and process controls**

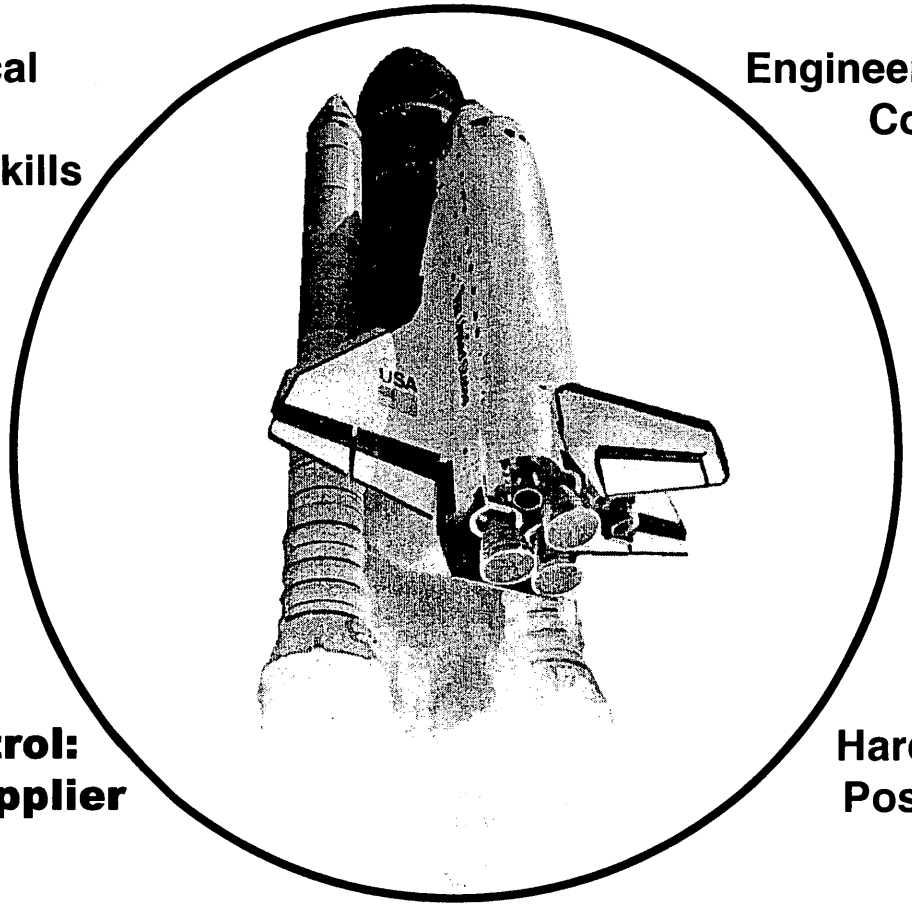
Reliability in simple terms is based on using the "same" material, the "same" process every time and sharing the process of change

Fly Safely

Requirements Control

Improve Technical Understanding and Assessment Skills

Engineering Design Control



Safety & Mission Assurance Participation

Launch Site Processing Insight/Oversight

Ongoing Static Test Motor Program

Process Control: Thiokol and Supplier

Hardware Recovery and Post flight Assessment

Aggressive Anomaly/Incident Investigation Process

Fly Safely Through Supplier Process Control

"A VARIETY OF TOOLS ARE REQUIRED"

ESTABLISH PROCESSES AND CONTROL CHANGES

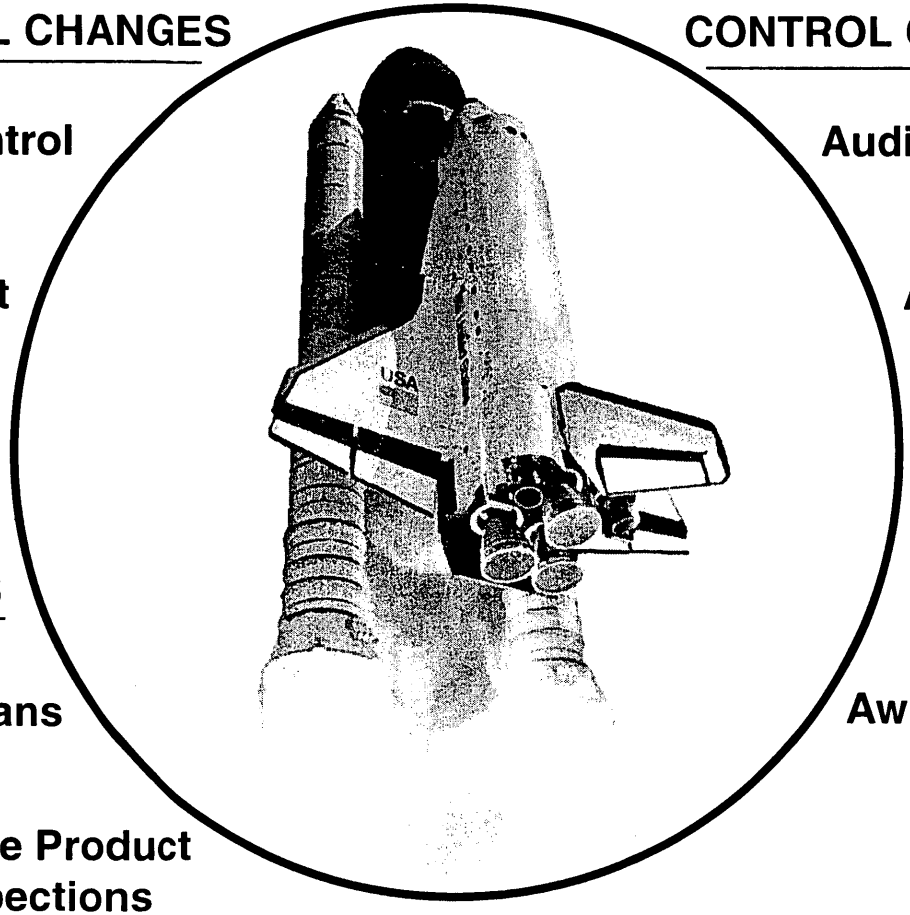
- Baseline Control
- Change Management Systems

MONITOR PROCESSES

- Inspection Plans
- On-site Product Inspections

REINFORCE PROCESS CONTROL CULTURE

- Audits
- Ad Hoc Visits and Teleconferences
- Symposiums
- Awards



Supplier Process Change Control

- Suppliers sign statement as part of RFQ process that they have or have not made changes since last procurement
- Supplier contract Terms and Conditions require notification of change(s)

> [illegible] PRODUCT CHANGES
> CONTRACTOR shall provide in writing advanced notification to the cognizant THIOKOL Procurement Representative of any change(s) in tooling, facilities, materials, or processes at the contracting supplier or their subtier supplier(s) that could affect the Thiokol contracted product. This includes, but is not limited to, fabrication, assembly, handling, inspection, acceptance, or testing.

- Notification required for
  - Thiokol suppliers
  - Thiokol supplier's subtier supplier(s)

RSRM Program Requirements

- World class vendor
- Fiber meets established technical requirements
  - Can survive weaving, carbonization and resin impregnation processes
  - Processing ease; slitting, wrapping etc...
  - Composite properties; meeting thermal and structural margins of safety in RSRM environment
- Fiber meets quality requirements
- Repeatability
- Periodic technical support (e.g. Anomaly investigations)
- Long term availability