Inter-center 3rd Generation team ranked over 70 technologies for
- Potential payoff to cost and safety
- Technological risk

Ranking process included study of technology activity, open discussion and consensus
- Analytical Hierarchy Process (AHP) used in final ranking

Technologies prioritized by
- A combined score of potential system payoff and technological risk
  Technology score = (cost + safety) * risk

Technologies coordinated with Aero-Space base activities
Efforts underway to make this annual process
Pathway to Safety and Affordability
Example 3rd Gen. Propulsion Candidate Investments

Spaceliner Requirements

- Hydrocarbon TSTO RBCC
- Numerical Propulsion Sys Sim
- H2 SSTO RBCC
- LongLife high T/W HC ROCKET
- LongLife LightWeight Materials
- Information Rich Instrumentation
- PDEBCC Rocket
- TSTO TBCC Airbreather
- PDEBCC Airbreather
- SSTO TBCC Airbreather
- High Performance Hydrocarbon Fuel
- LongLife High T/W H2 ROCKET
- Propulsion Life Prediction
- High Density H2
- Green Mono Prop RCS
- Integrated Propulsion Mgt System

Building Block Projects

- HC AirBreathing Testbed/Flight Experiment
- ART
- Reusable Altitude Compensating Eng
- Pulsed Detonation Engine
- Integrated Powerhead Development RACE
Hydrogen RBCC
Recent Accomplishments

♦ ART (Advanced Reusable Technologies)
  • Aerojet & Rocketdyne Flowpath Tested
    • Test Conducted From M 0 to Mach 8
    • Total Of 253 Test Conducted
    • Good Overall Performance
  • Several Firsts In Testing
    • Dynamic Trajectory Simulation (AAR -> RAM and RAM-> SCRAM))
    • SCRAM Testing @ High Dynamic Pressure (M8 @ 1,200 Psf)
    • Rocketdyne A-5 engine has logged over 1 hour of accumulated test time
  • Parametric Test Performed By Pennsylvania State University

♦ Trailblazer Concept Development
  – Lead By Glenn Research Center
  – Currently Testing @ GASL

♦ System Studies
  – Various Vehicle/Engine Combinations Being Studied
    • RBCC
    • TBCC
    • PDE
  – Sensitivity Trades Being Made
    • Trajectories
    • Fineness ratio
    • Payload capability
ART Future Plans

- Fabricate flight weight components
  - Rocketdyne combustor
  - Aerojet combustor
  - Aerojet ceramic ram/scram injectors
- Test selected components
- Document ART project

ART is scheduled to conclude in 2001
RAPTOR

(Revolutionary Airbreathing Propulsion Technology demonstrator)
Combined Cycle Propulsion Testbed

- Take the next logical step in combined cycle propulsion development
- Develop a flight-weight rocket based combined cycle engine system ground testbed
  - Sized capable of accelerating a self powered vehicle from Mach 0.8 to Mach 7
- Demonstrate RBCC engine system operation for air-augmented rocket, ramjet, and scramjet modes
- Provide testbed for evaluation of candidate innovative components
- Demonstrate flight weight engine system design and fabrication
- Evaluate engine system operational characteristics
- In test in 2004
- A testbed, not a prototype of an operational engine
- One of several airbreathing engine system testbeds leading to operational engine development(s) beginning in the 2010 - 2015 timeframe
Hydrocarbon Demonstrator Traceability

- The Hydrocarbon RBCC Engine Systems Demonstrator Provides Traceability to an Operational Launch Vehicle by ...

  • Developing a flight like, thermal & power balanced RBCC engine system

  • Demonstrating the operation of an RBCC engine system by testing from Mach 0 through Mach 7 in ground test

  • Performing vehicle design and propulsion system integration studies to show the applicability of RBCC to earth-to-orbit propulsion systems
On-Going Activities

- **Industry Team is Key to Development - HYPAR**
  - Preserve U.S. high speed propulsion industrial base
  - Rocketdyne - Management Lead
  - Pratt & Whitney - Technical Lead
  - Aerojet - Systems Integration Lead
  - MOA signed
  - FTC concurrence 8/4
  - Teaming agreement to be signed by 10/15
  - Program planning underway
  - Engine System Study final report week of 10/30

- **Flowpath Selection Team**
  - Team has been convening since June
    - Two representatives from each of the engine companies
    - One representative from Boeing Phantom Works
    - One representative from each participating NASA center (DFRC, GRC, LaRC, MSFC)
  - Data sharing initiated 7/24
  - Selection made 9/1 - Aerojet Strutjet Flowpath
'01 Plans

- Perform planning activity 11/00 - 4/01
- Put HYPAR consortium under contract
- Demonstrator vehicle activity led by LaRC
- Feed requirements for engine system
<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>'00</th>
<th>'01</th>
<th>'02</th>
<th>'03</th>
<th>'04</th>
<th>'05</th>
<th>'06</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flowpath Definition</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freejet testing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SRR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PDR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CDR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engine Sys. Def’n</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test Stand Dev.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Component testing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engine Sys. Fab.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engine Sys Test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leader Flight Exp’t</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicle Definition</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fab</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Checkout</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flight Test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follower Flight Experiment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Flight experiments not part of the RAPTOR project
Milestones

- 10/00 - Engine system study final report
- 9/01 - System Requirements Review (SRR)

Prioritized List of Activities

- Perform detailed project planning
- Implement system engineering framework
- Refine selected flowpath, engine systems concept, and structural approach
- Iterate propulsion/airframe integration