International Liquid Rocket Cooperation

The Case of the RD-180 Engine

Presented By Rob Bullock
Pratt and Whitney

52nd International Astronautical Congress
1-5 Oct 2001 / Toulouse, France
RD-180 Background

- RD-180 originally pursued by General Dynamics in early 90’s for a proposed Atlas upgrade.
- After General Dynamics merged with Martin Marietta which later became Lockheed Martin, the RD-180 engine studies solidified.
- In 1995, Lockheed Martin selected the team of NPO Energomash and Pratt & Whitney to develop the RD-180 for the Atlas IIAR (now Atlas III) and eventually for the Air Force EELV Launch Vehicle designs (Atlas V).
- In early 1997, RD AMROSS was formed, (the joint venture company between Pratt & Whitney and NPO Energomash), to establish production and sell flight engines/launch services to Lockheed Martin.
- A three-phased development and certification program is now near completion which certifies the RD-180 for use on the Atlas III, Atlas V MLV, Atlas V HLV Strap-on LRBs and the Atlas V HLV Core.
- The Russian-American cooperation in this endeavor is unprecedented.
Who is RDAMROSS?

- Marketing, sale, shipment and support services for RD-180 engines.

American / Russian Rocket Engine Joint Venture

- Premier upper stage engine developer / producer
- Funding source for RD-180 development
- Provides integration and launch support services
- Produces GSE for LMA engine checkout reqmts
- U.S. Co-Production source for the RD-180

- Premier booster engine developer / producer
- Developer/designer of RD-180 using RD-170 heritage
- Produces RD-180 engines for Lockheed Martin (Atlas)
- Provides engine integration and launch support services
- Performed numerous production transition programs

Pratt & Whitney
Space Propulsion

50% Owner

NPO Energomash

50% Owner

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Why International Cooperation / Partnership

- International Teams bring Strengths from both Partners - Broad International Experience Base
- International Teams bring Funding and other Resources from both Partners
- International Market opens Additional Opportunity for Product Evolution (RD-170, RD-180, RD-191)
- Resultant Evolved Products allow Reduced Development Costs and Schedule
- Derivative Engine Models with Mature Design and Technology Enable Increased Reliability
NPO Energomash

Russia’s Premier Booster Engine Designer and Manufacturer

- Founded in 1929 by V. Glushko
- Located in Khimky Russia (suburb of Moscow)
- Complete rocket engine design and manufacturing complex
- 2 million square feet of facilities
- Unique test stands

Unique Hydrodamper Test Stand
NPO Energomash Experience

More Than 2,300 Launches Made Using More Than 11,000 Engines

NPO Energomash has provided booster propulsion for these Russian launch vehicles

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RD-180 Design Background

**RD-180 Heritage**

- RD-180 derived from the NPO EM designed RD-170 (man-rated, reusable)
- RD-170 component designs accumulated more than 900 tests and 100,000 seconds of test time
- RD-180 has 70% common hardware, 30% scaled hardware from RD-170
- Oxidizer rich staged combustion provides highest performance for LOX/kerosene engines
- High chamber pressure for high performance
RD-180 Engine Characteristics

**Characteristics Demonstrate Heritage to RD-170**

- Two chamber derivative of the RD-170
- Identical chambers, scaled turbopumps
- Staged combustion cycle - LOX rich PB
- LOX/kerosene propellants
- 2 thrust chambers (+/- 8° gimbal)
- LOX & fuel boost pumps
- Single shaft high pressure turbopump
  - 2 stage fuel pump
  - single stage LOX pump
  - single stage turbine
- Self contained hydraulic system (valves, TVC) powered with kerosene from fuel pump
- Hypergolic ignition
### RD-180 Performance Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Specification</th>
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<tbody>
<tr>
<td>Thrust SL/Vacuum</td>
<td>390K kgf (3.8 MN) / 423 K kgf (4.2 MN)</td>
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<tr>
<td>Isp SL/Vac</td>
<td>311.3 sec / 337.8 sec</td>
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<tr>
<td>Cycle</td>
<td>Staged Combustion, Oxidizer rich turbine drive</td>
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<tr>
<td>Throttle Range</td>
<td>47% to 100%</td>
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<tr>
<td>Chamber Pressure</td>
<td>25.7 MPa</td>
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<tr>
<td>Mixture Ratio (O/F)</td>
<td>2.72 ± 7%</td>
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<tr>
<td>Length</td>
<td>3.5 m</td>
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<tr>
<td>Maximum diameter</td>
<td>3.1 m</td>
</tr>
<tr>
<td>Chamber exit diameter</td>
<td>1.4 m</td>
</tr>
<tr>
<td>Nozzle area ratio</td>
<td>36.4 : 1</td>
</tr>
<tr>
<td>Weight (dry)</td>
<td>5,480 kg</td>
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</table>
RD-180 Enables Atlas Family Growth

Atlas Launch Vehicle Family by Lockheed Martin Astronautics

21st Century Growth

Atlas II
Atlas IIA
Atlas IIAS
Atlas III (SEC)
Atlas III (DEC)
Atlas V (400 Series) (0-3 SRBs)
Atlas V (500 Series) (0-5 SRBs)
Atlas V (HLV)

RD-180 Engine
Single Engine Centaur
Common Centaur
Lox Tank Stretch
3.8m Common Core Booster
5m PLF GSO Kit
Liquid Strapons
SRBs

(k kg) (k lb)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
RD-180 Engine Features

Enhance Launch Vehicle Effectiveness

- Smooth and continuous throttling from 47% power to 100%
- Atlas V booster engine interchangeability with Atlas III
- Self-contained engine pneumatic system, 4 fewer fluid interfaces than with previous engine
- Self-contained thrust vector control actuators; no auxiliary roll system required
- Self-contained hydraulics after engine start
- Reduced engine integration and checkout time, 12 days vs. 80 for previous engine
- Possibility to use single engine in 2nd stage
- Reduced engine cost
RD-180 Engine Features

Multiple Bell Nozzle
Common use in Russian designs

- Multiple chambers allow
  - faster gimbaling/smaller actuators
  - manufacturing efficiency
  - full 3-axis flight control without an auxiliary propulsion system for roll control
  - shorter engine length
RD-180 Engine Features

High Thrust Operation with Throttle Capability

Engine characteristics have direct benefit to vehicle

High power capability allows vehicle growth and flexibility in trajectory

Power Margin allows robust vehicle structure and simpler manufacturing techniques

Throttltability allows for control of “Max Q” and propellant depletion structural loads

Engine health check during start transient
RD-180 Program Key Events And Success

- LM Selects P&W/EM Team to Develop and Co-produce RD-180
- First RD-180 Development Test
- RD AMROSS Founded. Contracts with LM Established
- P&W/EM Contract for RD-180 Development Program
- Master Support and Licensing Agreement
- Engine 4A Tests in Huntsville
- First Production Engine Delivery to LM
- RD-180 Cert Testing Complete for Atlas V MLV
- Delivery of 4 Production Engines
- RD-180 Cert Complete for Atlas III
- Delivery of 3 Production Engines
- Successful Atlas III First Launch

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RD-180 Certification

3 – Phase Program

“Test as you fly”

Atlas III

Development

Atlas V MLV

Development Cert

Atlas V HLV

Demonstration Cert

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RD-180 Test Time Accumulation

Consistent Swift Progress Toward Engine Maturity and Demonstrated Reliability

Cumulative Test Time

Projected

1st Flight (AC-201)

42 Engines 153 tests

To Date (Sept 2001) 27,550 sec

Start, Nov 1996

Time (seconds)

01-Jan-96 31-Dec-96 31-Dec-97 31-Dec-98 31-Dec-99 30-Dec-00 30-Dec-01 30-Dec-02

0 5000 10000 15000 20000 25000 30000 35000
Successful First Flight!

AC-201 with Eutelsat W4 Payload, May 24, 2000

Nominal RD-180 performance

87% Cruise Operation

Boost Stage Separation
Production Engines

Engine Currently in Serial Production

- 8 flight engines delivered to Lockheed Martin to date
- 1 engine flown (successful launch of AC-201)
- Built in Russia, flown to Denver, launched from Cape Canaveral
RD-180 International Venture - Conclusions

- RD-180 Program has been Highly Successful
- New “International” Engine Developed with Resources from Both Countries
- Lasting Partnership with Mutual Trust, Respect, and Cooperation has been Forged
- Both Companies (and Countries) have Benefited
  - Expanded Markets
  - Expanded Product Line
  - Low Development Cost
  - Highly Reliable and State-of-the-Art Engine