

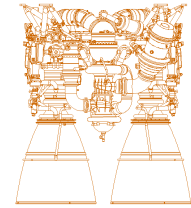
**International Liquid Rocket Cooperation**  
**The Case of the RD-180 Engine**

***Presented By Rob Bullock***  
***Pratt and Whitney***

**52nd International Astronautical Congress**  
**1-5 Oct 2001 / Toulouse, France**

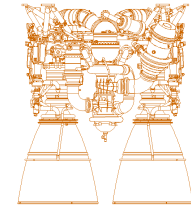
# RD-180 Background

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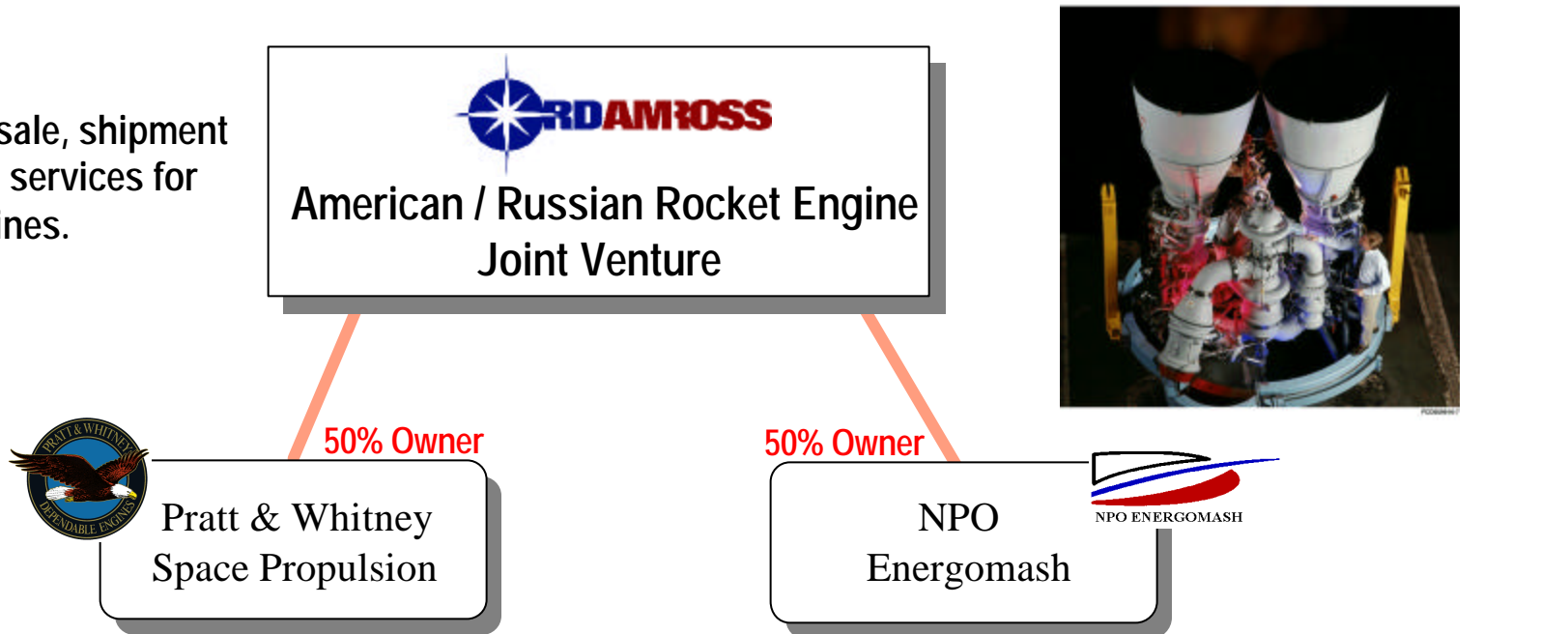


- RD-180 originally pursued by General Dynamics in early 90's for a proposed Atlas upgrade.
- After General Dynamics merged with Martin Marietta which later became Lockheed Martin, the RD-180 engine studies solidified.
- In 1995, Lockheed Martin selected the team of NPO Energomash and Pratt & Whitney 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 R D A M R O S S ?



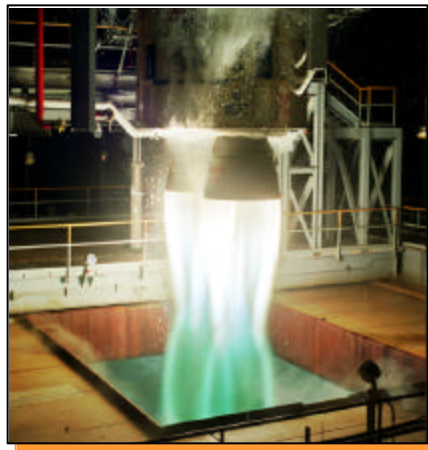
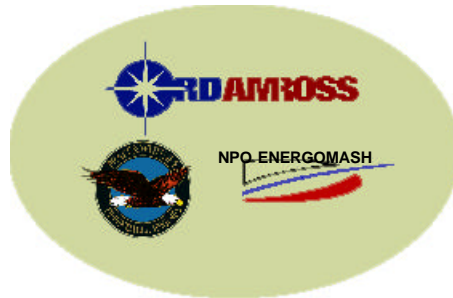
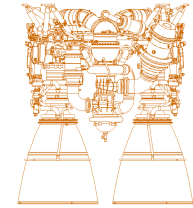
- Marketing, sale, shipment and support services for RD-180 engines.



- 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

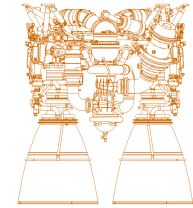
- Premier booster engine developer / producer
- Developer/designer of RD-180 using RD-170 heritage
- Produces RD-180 engines for Lockheed Martin (Atlas)
- Provides engine integration and launch support services
- Performed numerous production transition programs

# 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

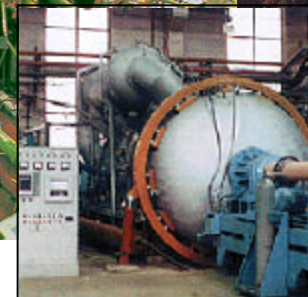
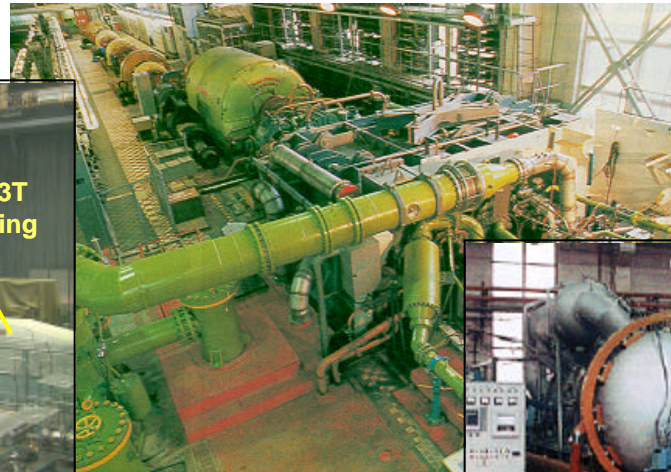
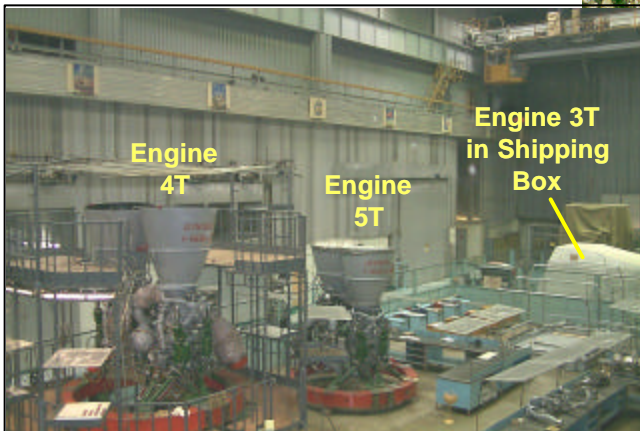
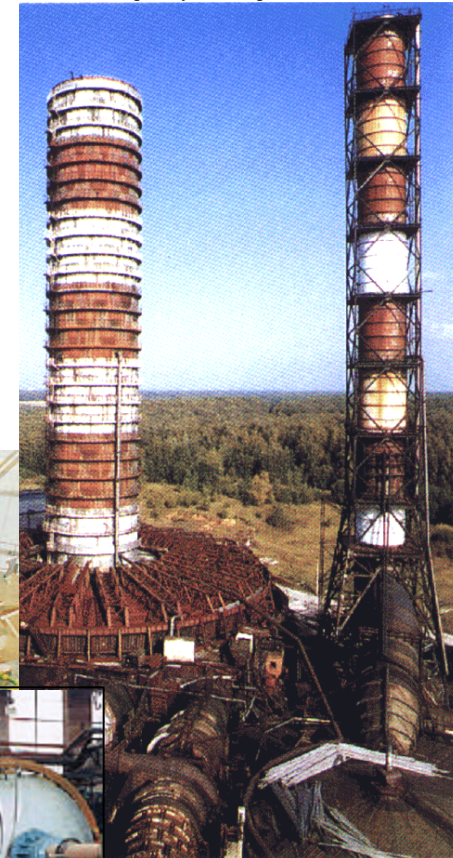
# NPO Energomash



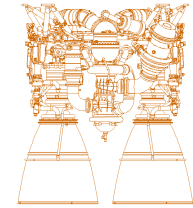
## *Russia's Premier Booster Engine Designer and Manufacturer*

- 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

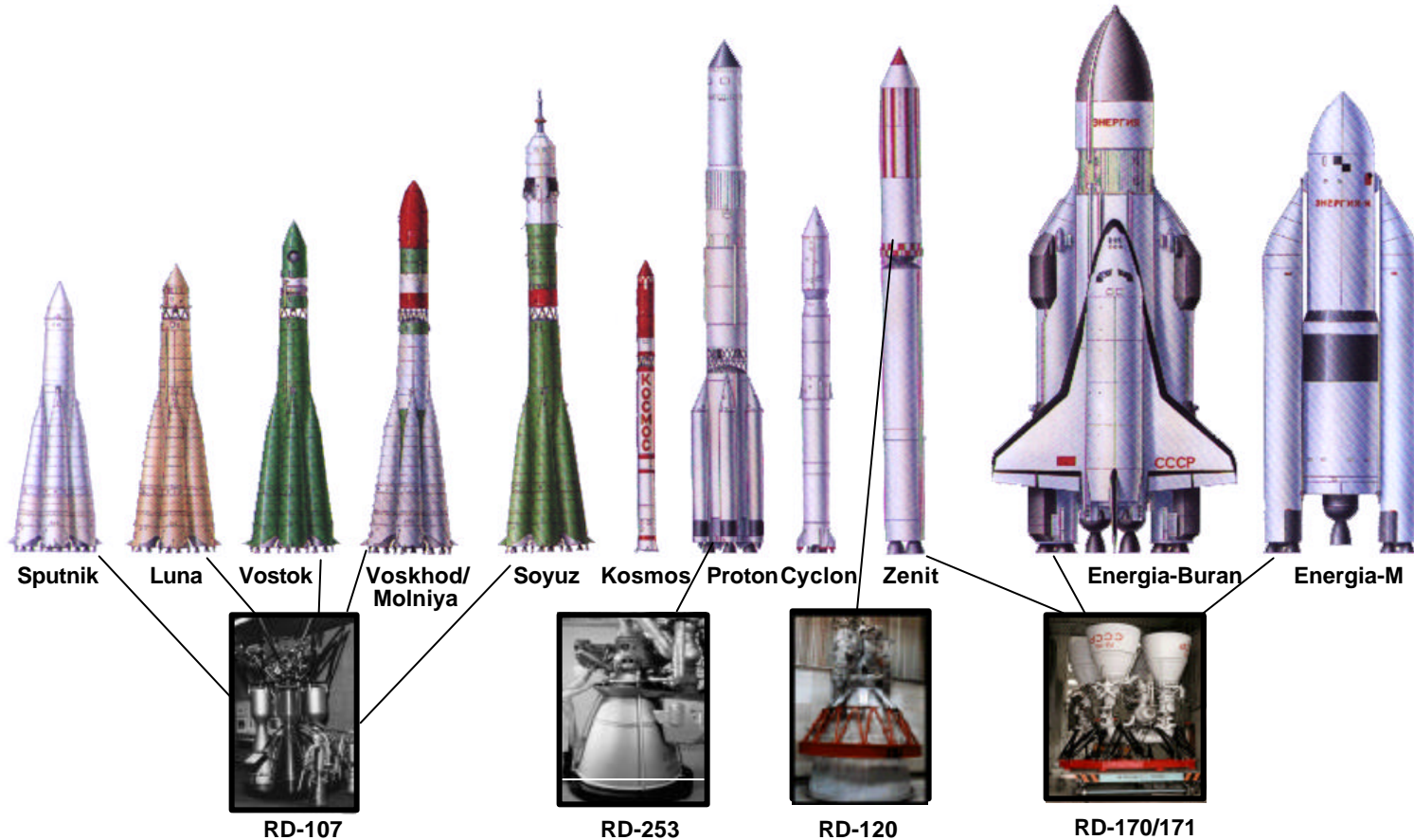
Unique Hydromper Test Stand



# NPO Energomash Experience



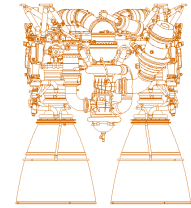
*More Than 2,300 Launches Made Using More Than 11,000 Engines*



NPO Energomash has provided booster propulsion for these Russian launch vehicles

*52nd International Astronautical Congress  
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# RD-180 Design Background



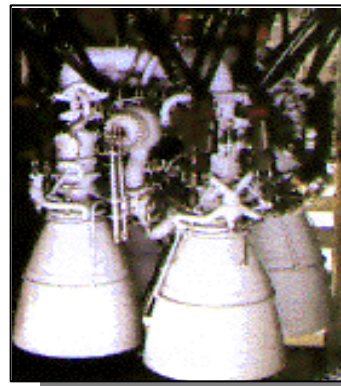
## *RD-180 Heritage*

- 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*  
*(0.9M lb thrust)*



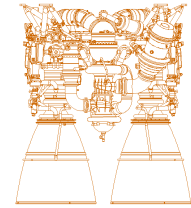
*RD-170*  
*(1.8M lb thrust)*



*Energia/Buran*

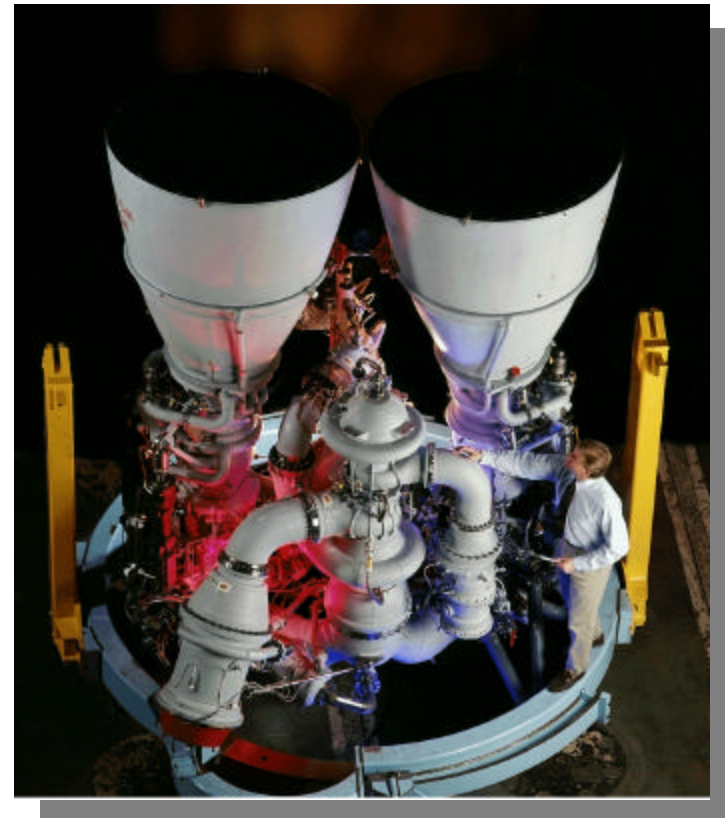


# RD-180 Engine Characteristics



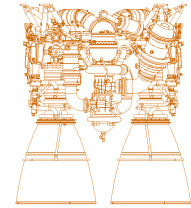
## *Characteristics Demonstrate Heritage to RD-170*

- 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

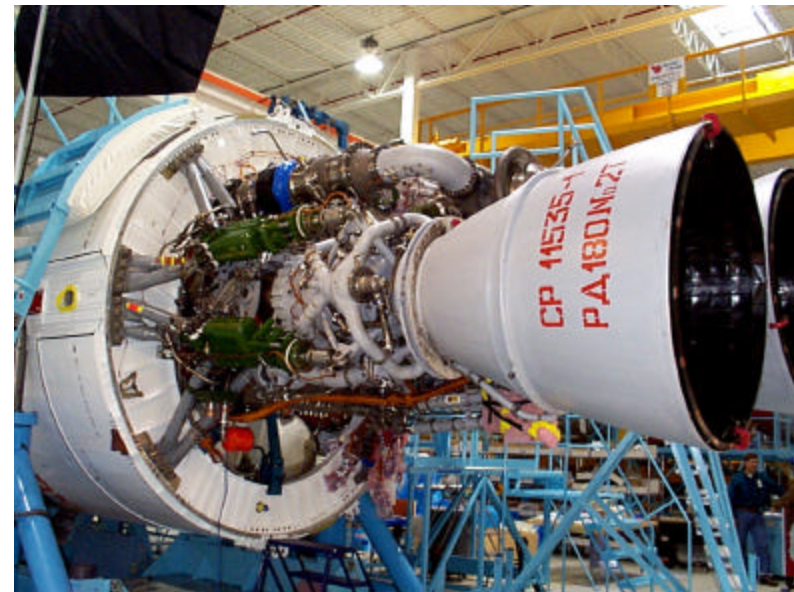




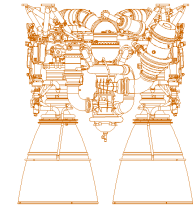
# RD-180 Performance Characteristics



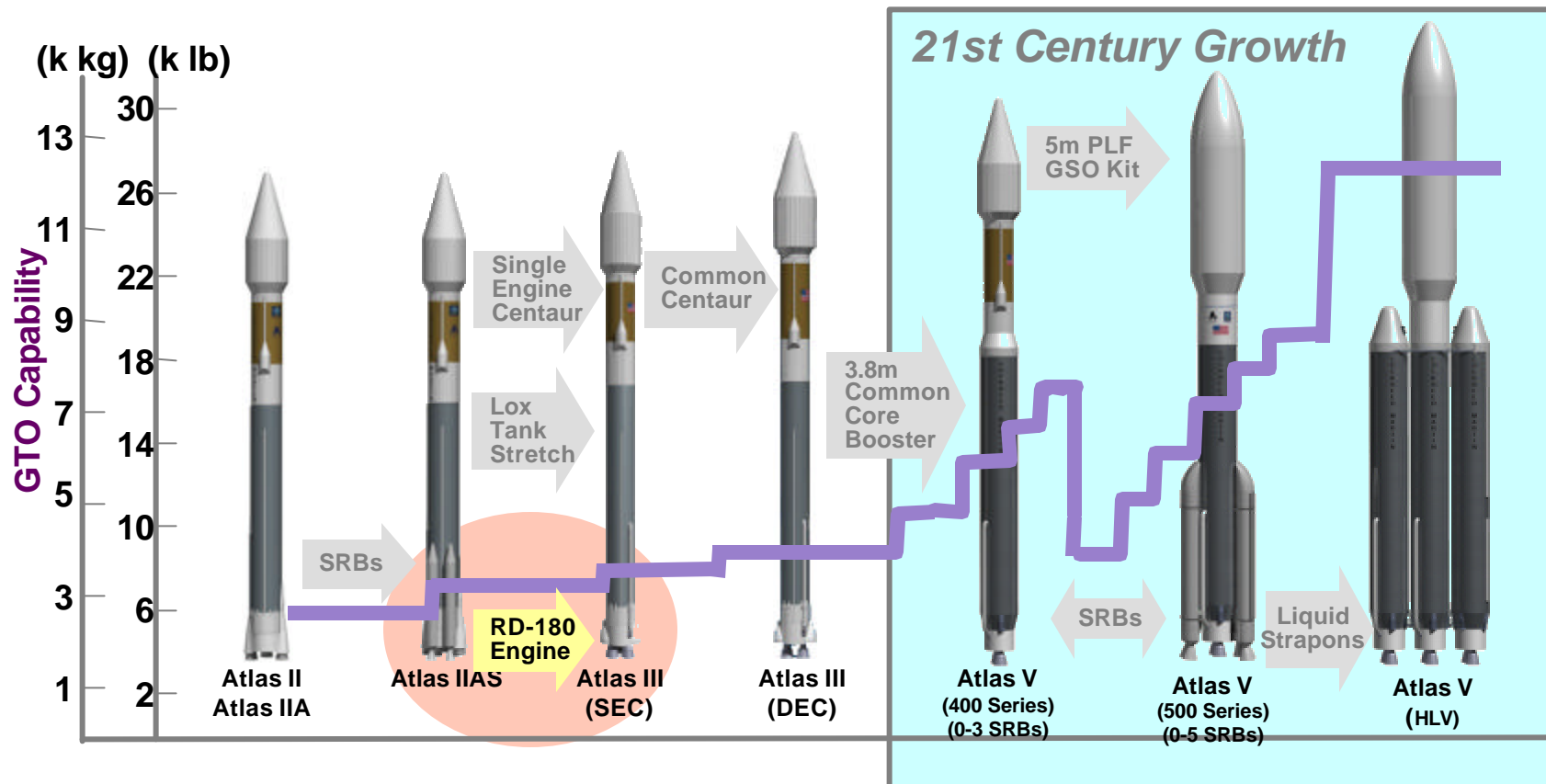
Thrust SL/Vacuum	390K kgf (3.8 MN) / 423 K kgf (4.2 MN)
Isp SL/Vac	311.3 sec / 337.8 sec
Cycle	Staged Combustion, Oxidizer rich turbine drive
Throttle Range	47% to 100%
Chamber Pressure	25.7 MPa
Mixture Ratio (O/F)	2.72 ± 7%
Length	3.5 m
Maximum diameter	3.1 m
Chamber exit diameter	1.4 m
Nozzle area ratio	36.4 : 1
Weight (dry)	5,480 kg



# RD-180 Enables Atlas Family Growth

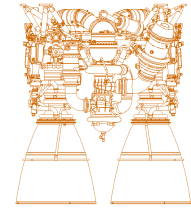


## *Atlas Launch Vehicle Family by Lockheed Martin Astronautics*



# RD-180 Engine Features

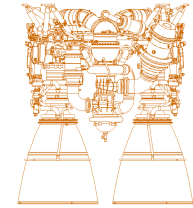
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## *Enhance Launch Vehicle Effectiveness*

- 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

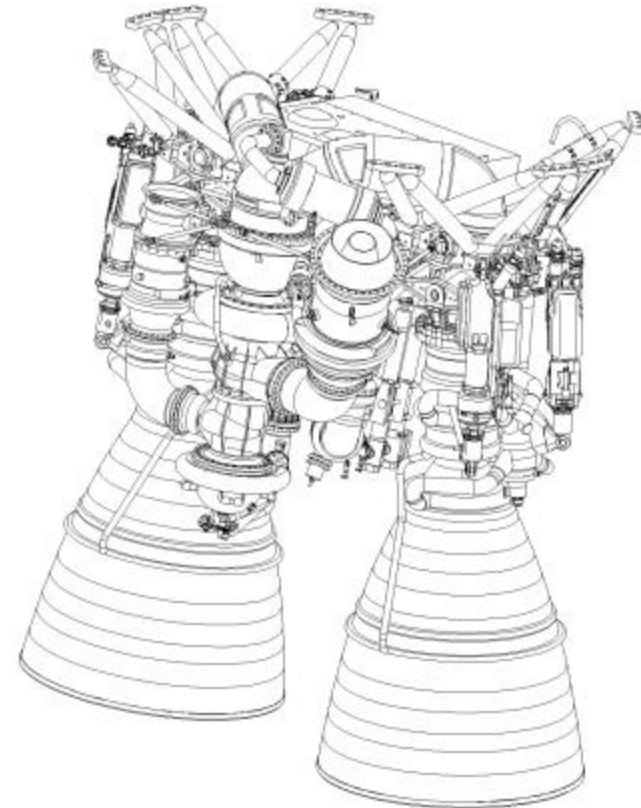
# RD-180 Engine Features



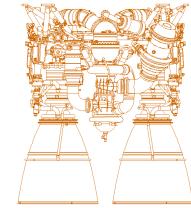
## *Multiple Bell Nozzle*

*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



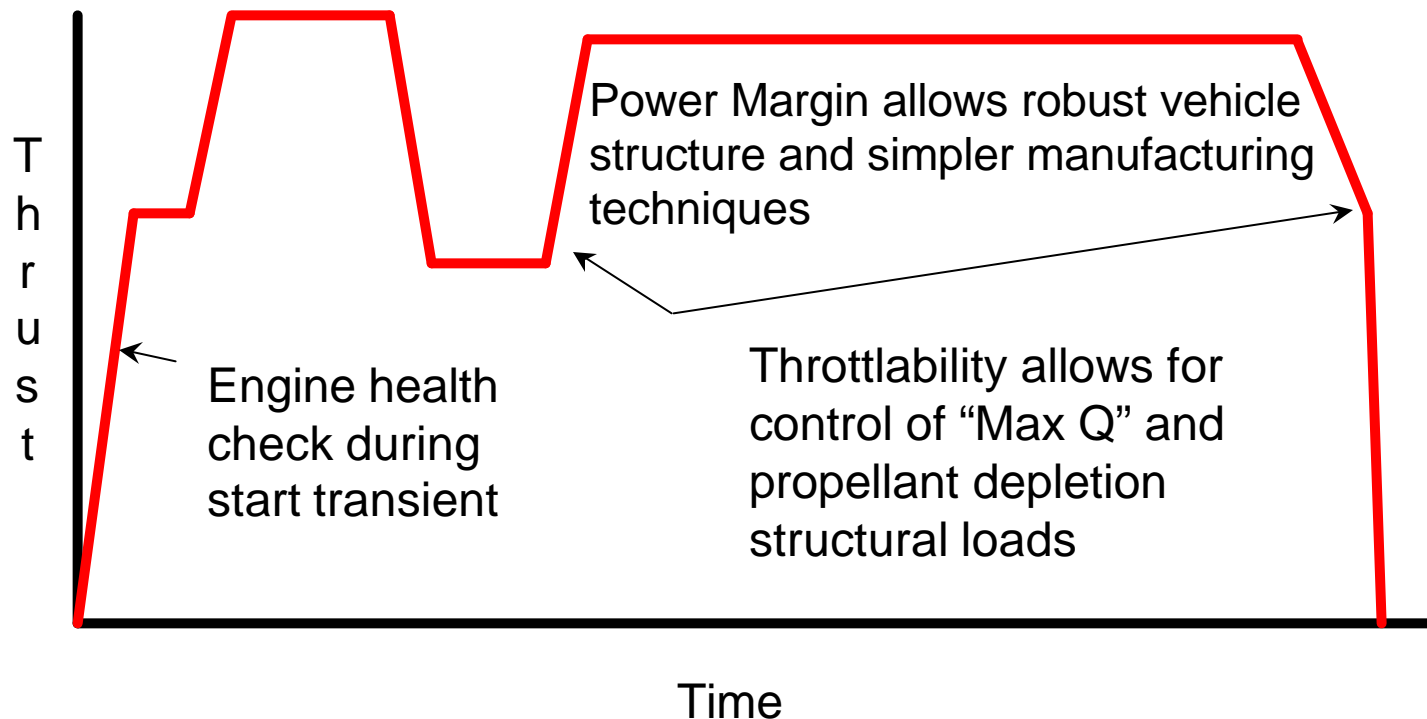
# RD-180 Engine Features



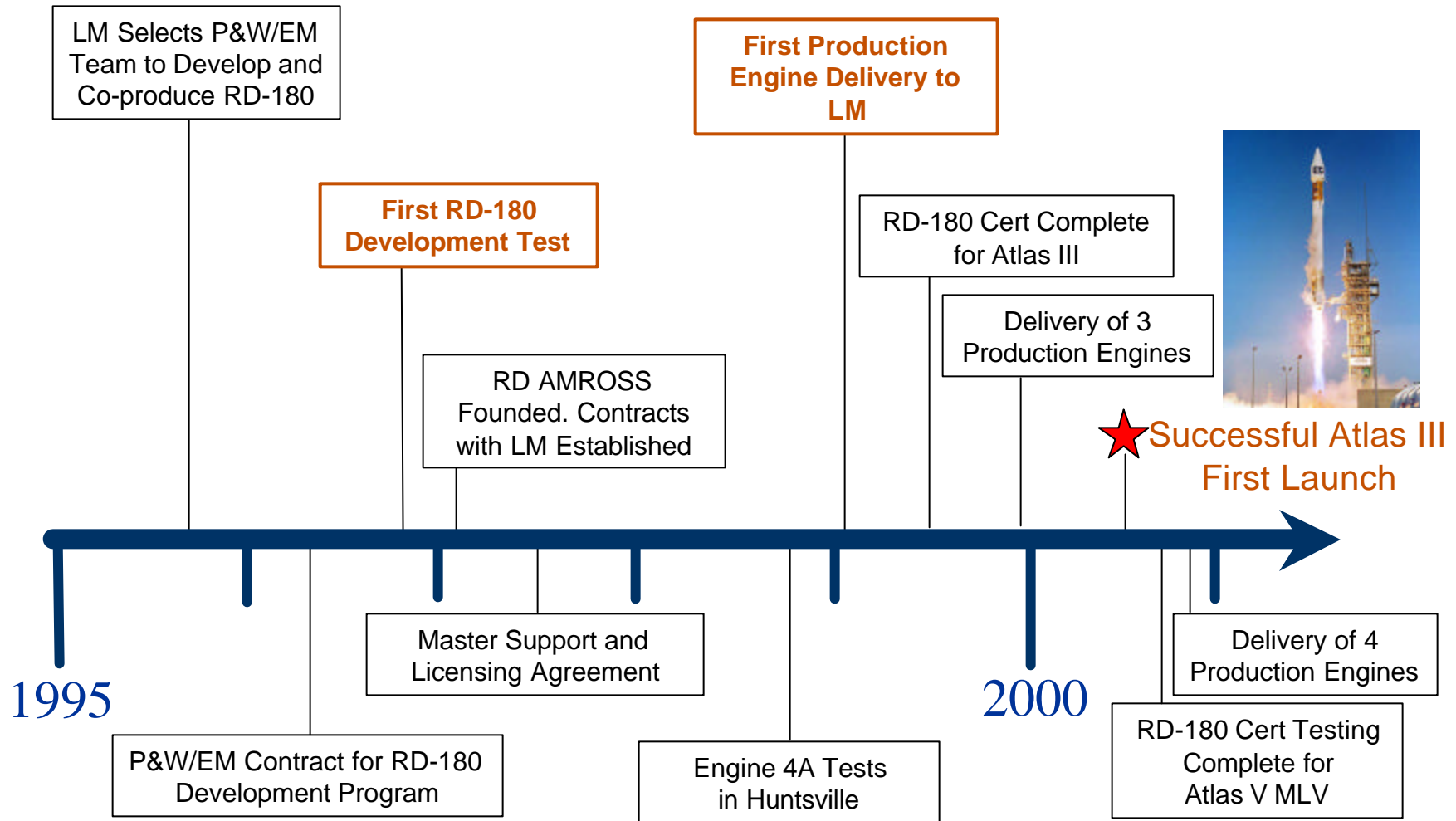
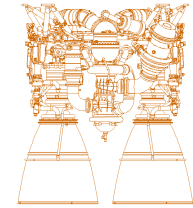
## *High Thrust Operation with Throttle Capability*

*Engine characteristics have direct benefit to vehicle*

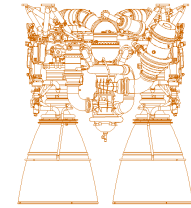
High power capability allows vehicle growth and flexibility in trajectory



# RD-180 Program Key Events And Success

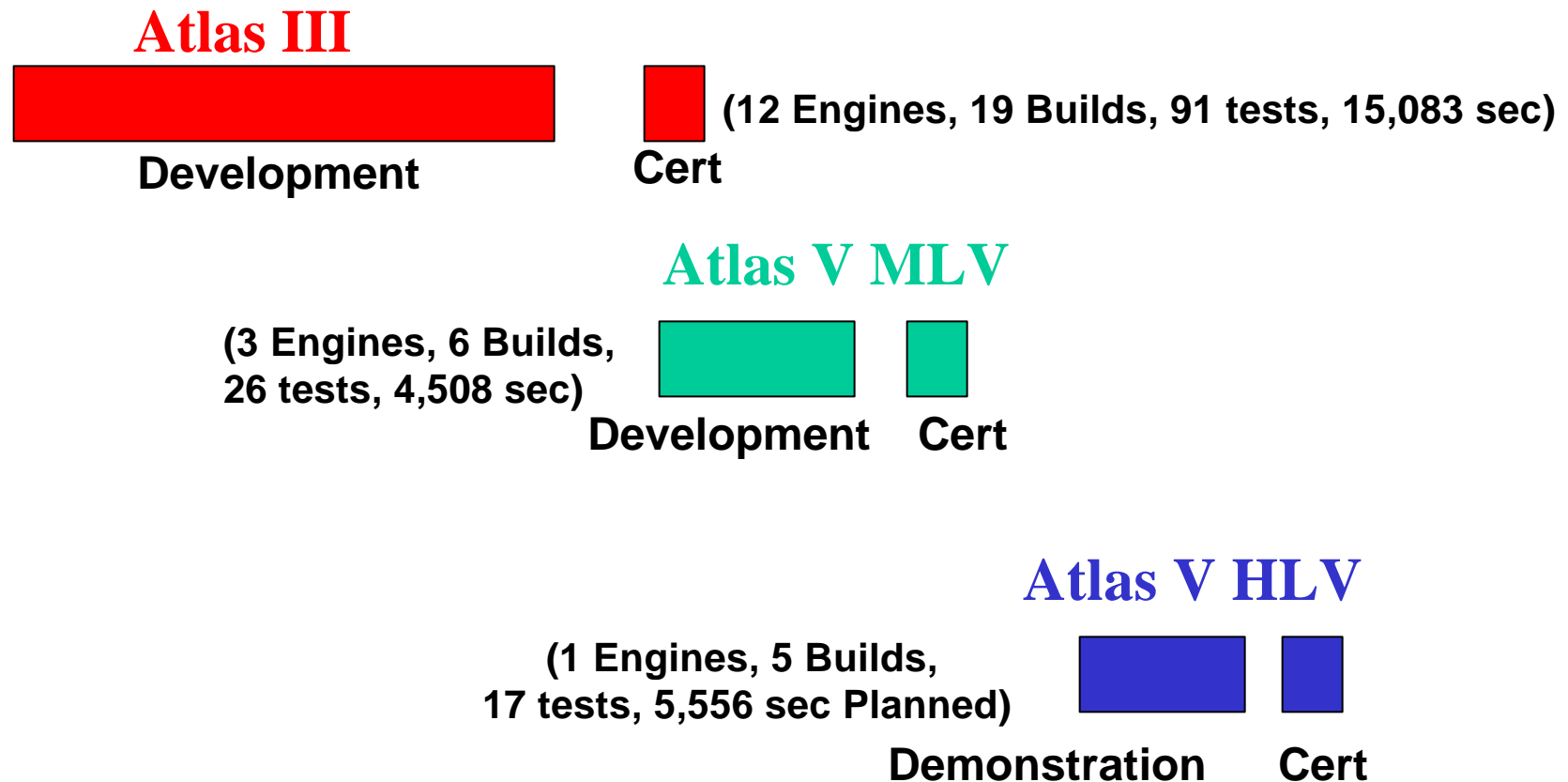


# RD-180 Certification

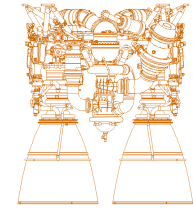


## 3 – Phase Program

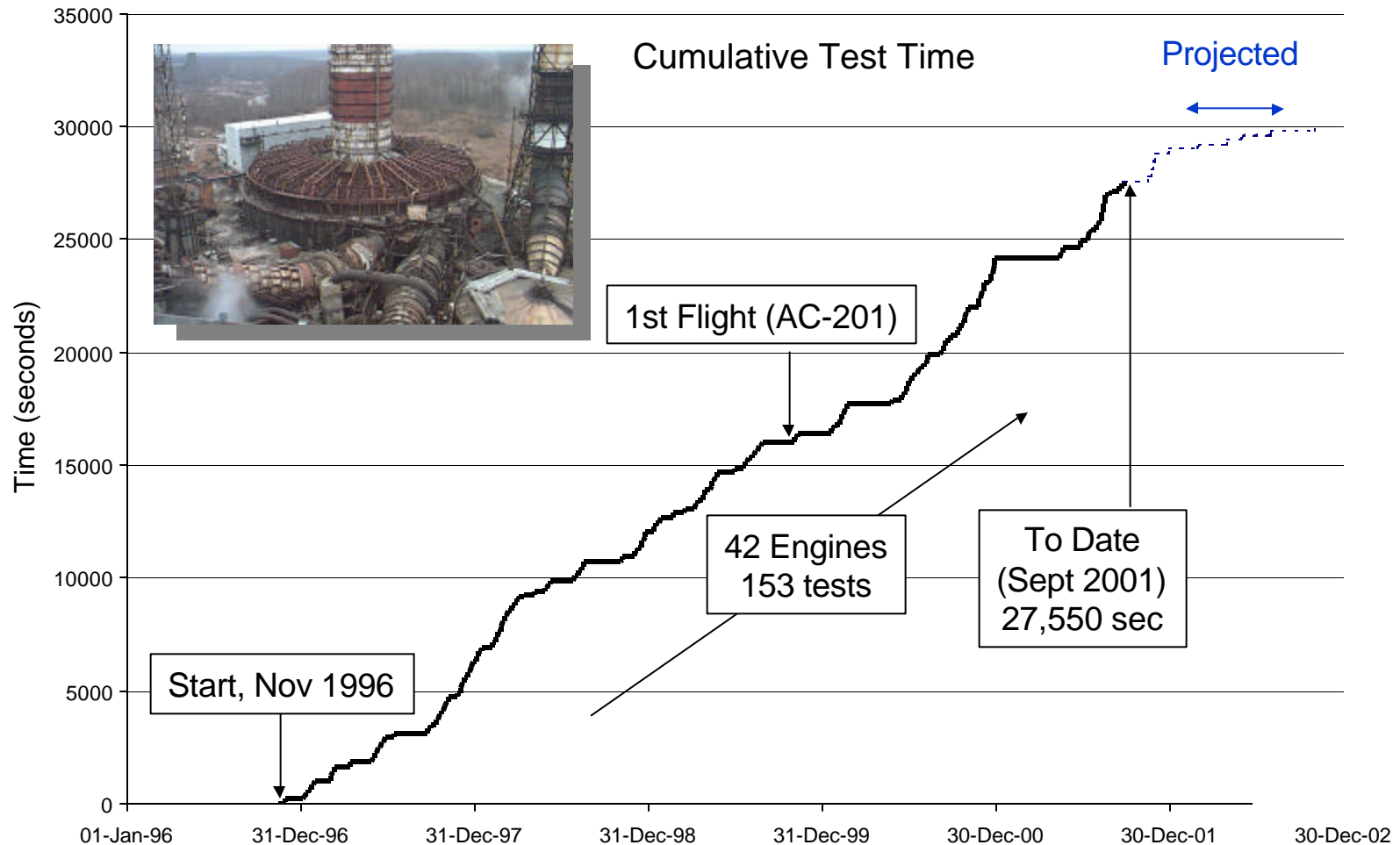
“Test as you fly”



# RD-180 Test Time Accumulation

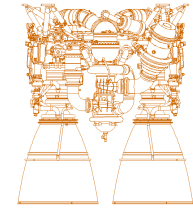


*Consistent Swift Progress Toward Engine Maturity and Demonstrated Reliability*





# Successful First Flight !



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

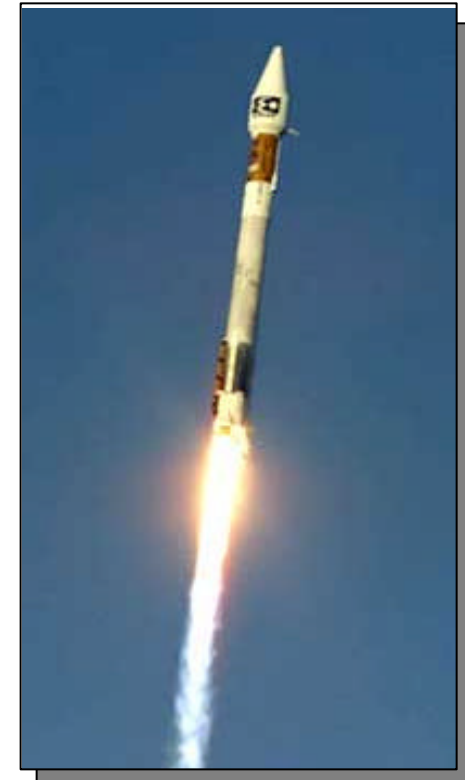
## Nominal RD-180 performance



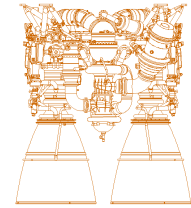
87% Cruise Operation



Boost Stage Separation



# Production Engines

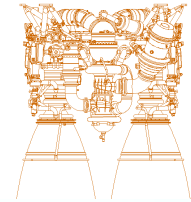


## *Engine Currently in Serial Production*

- 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