Worldwide Space Launch Vehicles and their Mainstage Liquid Rocket Propulsion

Yuri’s night observance
Presenter: Dr. S. Rahman, NASA SSC

Greater New Orleans AIAA Section
Monday - April 13, 2010
German “Aggregat” A-4 (V-2)

Source: www.b14643.de/Spacerockets_1
Space faring Countries

- USA (Atlas, Titan, Shuttle, Delta, and in dev Falcon)
- USSR (Soyuz, Proton, Zenit, Tsyklon, and in dev Angara)
- Russia (Soyuz, Proton)
- Ukraine (Zenit, Tsyklon)
- India (PSLV, GSLV)
- Japan (H-I, H-IIA/B)
- China (CZ series, aka Long March)
- Europe-ESA (Ariane, and in-dev Vega)
- France (Ariane)
  - Italy (In dev Vega)
  - Brazil (In dev)
  - Australia (In dev)
  - Koreas (In dev)
  - Etc.

Discuss Liquid Rocket Engine propelled vehicles
Solid rocket based heritage not elaborated here.
USA

- A-4
- Titan
- Atlas
- Delta
- Mercury, Gemini, Apollo,
- Shuttle
- Future: Falcon, Taurus, ...

Sources:
http://www.designation-systems.net/dusrm/app3/index.html
www.astronautix.com
www.globalsecurity.org/space/world
American A-4

RELEASED - Printed documents may be obsolete; validate prior to use.
US Apollo

Saturn booster (1969-74)

J-2 (LOX/LH)

J-2 x 5 (LOX/LH)

F-1 x 5 (LOX/RP)

RELEASED - Printed documents may be obsolete; validate prior to use.
US Delta IV

Delta IV (2001 – present)

RL-10B (LOX/LH)

RS-68 (LOX/LH)

RELEASED - Printed documents may be obsolete; validate prior to use.
US Atlas

Atlas V (2002 – present)

RL-10A-4 (LOX/LH)

RD-180 (LOX/RP) (Russian)

RELEASED - Printed documents may be obsolete; validate prior to use.
US Titan

Titan IV (1989-94)

LR-91 (N2O4/UDMH)

LR-87 (N2O4/UDMH)

RELEASED - Printed documents may be obsolete; validate prior to use.
US Shuttle

Space Shuttle (1981-present)

SSME (LOX/LH)

RELEASED - Printed documents may be obsolete; validate prior to use.
US Falcon

Falcon 1 (2009-present)

Kestrel (LOX/RP)

Merlin (LOX/RP)

RELEASED - Printed documents may be obsolete; validate prior to use.
Soviet “A-4”

W-1, R-1

RELEASED - Printed documents may be obsolete; validate prior to use.
USSR/Ukraine Zenit

RD-120 (LOX/RP)

RD-171 (LOX/RP)
Ukraine Tsyklon

Tsyklon (1980-present)

RD-261 (N2O4/UDMH)

RD-262 (N2O4/UDMH)

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USSR/Russia Proton

Proton

RD-0210 x 3
(N2O4/UDMH)

RD-275 x 6
(N2O4/UDMH)

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INDIA SLV’s

- PSLV & variants
- GSLV & variants
India PSLV

PSLV

LVS x 2
(4\textsuperscript{th} Stage
N2O4/UDMH)

Vikas x 4
(2\textsuperscript{nd} Stage,
N2O4/UDMH)

PSLV

RELEASED - Printed documents may be obsolete; validate prior to use.
India GSLV

Vikas-4
(2\textsuperscript{nd} Stage, N2O4/UDMH)

Vikas-2
(Strap-ons, N2O4/UDMH)

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JAPAN SLV’s

• M-V (solid rocket)
• H-I
• H-II
Japan H-II

LE-5/5A/5B (LOX/LH)

LE-7 (LOX/LH)

RELEASED - Printed documents may be obsolete; validate prior to use.
Japan H-IIA/B

H-IIA (1989-94)

LE-5B (LOX/LH)

LE-7A x 2 (LOX/LH)

RELEASED - Printed documents may be obsolete; validate prior to use.
China “A-4”

A-4 and DF-1

USSR RD-100 (LOX/Alcohol)
Chang Zheng - ELV

YF-24
(N2O4/UDMH)

YF-21 = YF-20 x 4
(N2O4/UDMH)

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Chang Zheng – Human Rated

YF-26
(N2O4/UDMH)

YF-21 = YF-20 x 4
(N2O4/UDMH)

YF-25
(N2O4/UDMH)
Launch Sites

Source:
AIAA Paper 2010-974, Rahman, Keim, and Zeender
IAC Paper IAC-09-D1.5.1, Tomei and Chang
Launch Activity

CIS

USA

Emerging

RELEASED - Printed documents may be obsolete; validate prior to use.
HLV Reliability for Different Countries

Source: IAC-09-D1.5.1 … “51 Years of Space Launches and Failures” E. Joe Tomei and I-Shih Chang, The Aerospace Corporation, U.S.A.

### Table: HLV Reliability

<table>
<thead>
<tr>
<th>Country</th>
<th>Reliability</th>
<th>Success Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.</td>
<td>93.3%</td>
<td>261 / 279 = 93.5%</td>
</tr>
<tr>
<td>CIS/USSR</td>
<td>87.6%</td>
<td>308 / 351 = 87.7%</td>
</tr>
<tr>
<td>Europe</td>
<td>92.1%</td>
<td>42 / 45 = 93.3%</td>
</tr>
<tr>
<td>HLV</td>
<td>90.4%</td>
<td>611 / 675 = 90.5%</td>
</tr>
</tbody>
</table>

### Graph:

- **HLV**: Demonstrated Reliability (%)
- **2009-08-01**
- **U.S.**, **CIS/USSR**, **Europe**: Number of Launches

**Legend**:
- Europe fail
- CIS/USSR fail
- U.S. fail
- Europe succ
- CIS/USSR succ
- U.S. succ

**Note**: Printed documents may be obsolete; validate prior to use.
MLV Reliability for Different Countries

Source: IAC-09-D1.5.1 … “51 Years of Space Launches and Failures” E. Joe Tomei and I-Shih Chang, The Aerospace Corporation, U.S.A.
Demonstrated Reliability
- Failure Causes (US) -

SPACE FLIGHT FAILURES BY SYSTEM

TITAN ATLAS THOR DELTA SCOUT STS SATURN

108 FAILURES / 972 FLIGHTS

1957–1987

NUMBER OF FAILURES

PROPULSION AVIONICS ELECTRICAL STRUCTURE STAGING/SEP OTHER UNKNOWN

RELEASED - Printed documents may be obsolete; validate prior to use.
What’s Next - Russia

Angara Series

U/S LRE’s

Boost LRE’s

RELEASED - Printed documents may be obsolete; validate prior to use.
What's Next - China

YF-77 (LOX/LH)

YF-100 (LOX/RP1)

Released - Printed documents may be obsolete; validate prior to use.
What’s Next - ESA

Vega + Soyuz + Ariane = Fleet
What’s Next - Japan

H-II Series

H-II
H-IIA
H-IIB

H-X Series

LE-X
(LOX/LH)

RELEASED - Printed documents may be obsolete; validate prior to use.
General Trends

• Space launch vehicle begins with a basic propulsion stage, and serves as a missile or small launch vehicle; many are traceable to the 1945 German A-4

• Increasing stage size, and increasingly energetic propulsion allows for heavier payloads and greater Earth to Orbit lift capability

• Liquid rocket propulsion began with use of storable (UDMH/N2O4) and evolved to high performing cryogenics (LOX/RP, and LOX/LH)

• Growth versions of SLV’s rely on strap-on propulsive stages of either solid propellants or liquid propellants
Tsiolkovsky  Goddard  Oberth

Korolyov  Von Braun  Tsien

Yuri  Abdul Kalam

... and many more!