Worldwide Space Launch Vehicles and their Mainstage Liquid Rocket Propulsion

Yuri’s night observance

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Greater New Orleans AIAA Section

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German “Aggregat” A-4 (V-2)

Source: www.b14643.de/Spacerockets_1

A-4 (1946)

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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

A-4 (1946)

Ofen
(LOX/Alcohol)

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US Apollo

Saturn booster (1969-74)

J-2 (LOX/LH)

J-2 x 5 (LOX/LH)

F-1 x 5 (LOX/RP)

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US Atlas

Atlas V (2002 – present)

RL-10A-4 (LOX/LH)

RD-180 (LOX/RP) (russian)

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US Titan

Titan IV (1989-94)

LR-91 (N2O4/UDMH)

LR-87 (N2O4/UDMH)

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US Shuttle

Space Shuttle (1981-present)

SSME (LOX/LH)

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US Falcon

Falcon 1 (2009-present)

Kestrel (LOX/RP)

Merlin (LOX/RP)

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Soviet “A-4”

W-1, R-1

RD-100
(LOX/Alcohol)

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USSR/Russian Soyuz

RD-0110
(LOX-RP)

RD-107
(strap-ons
LOX-RP)

RD-108
(core – LOX/RP)

Soyuz (1989-94)

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USSR/Ukraine Zenit

RD-120 (LOX/RP)

RD-171 (LOX/RP)

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Ukraine Tsyklon

Tsyklon (1980-present)

RD-261
(N2O4/UDMH)

RD-262
(N2O4/UDMH)

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USSR/Russia Proton

Proton

RD-275 x 6 (N2O4/UDMH)

RD-0210 x 3 (N2O4/UDMH)

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INDIA SLV’s

- PSLV & variants
- GSLV & variants
India PSLV

PSLV

LVS x 2
(4th Stage, N2O4/UDMH)

Vikas x 4
(2nd Stage, N2O4/UDMH)

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

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

Vikas-4
(2nd Stage, N2O4/UDMH)

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JAPAN SLV’s

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

H-IIA (1989-94)

LE-5B
(LOX/LH)

LE-7A x 2
(LOX/LH)

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China “A-4”

A-4 and DF-1

USSR RD-100
(LOX/Alcohol)

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Chang Zheng - ELV

YF-24
(N2O4/UDMH)

YF-21 = YF-20 x 4
(N2O4/UDMH)
Chang Zheng – Human Rated

YF-26
(N2O4/UDMH)

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

YF-25
(N2O4/UDMH)

RELEASED - Printed documents may be obsolete; validate prior to use.
Source:
AIAA Paper 2010-974, Rahman, Keim, and Zeender
IAC Paper IAC-09-D1.5.1, Tomei and Chang

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Launch Activity

CIS

USA

Emerging

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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.
Demonstrated Reliability

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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

1957–1987

108 FAILURES / 972 FLIGHTS

NUMBER OF FAILURES

PROPULSION AVIONICS ELECTRICAL STRUCTURE STAGING/SEP OTHER UNKNOWN

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What’s Next - Russia

Angara Series

U/S LRE’s

Boost LRE’s

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What’s Next - China

YF-77 (LOX/LH)
YF-100 (LOX/RP1)

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What's Next - ESA

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

H-II Series

H-X Series

LE-X (LOX/LH)

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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

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... and many more!