



Worldwide Space Launch Vehicles and their Mainstage Liquid Rocket Propulsion

98% DRAFT

Yuri's night observance

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Greater New Orleans AIAA Section

Monday - April 13, 2010

German "Aggregat" A-4 (V-2)

Source: www.b14643.de/Spacerockets_1



**Ofen-B
(LOX/Alcohol)**

A-4 (1946)

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

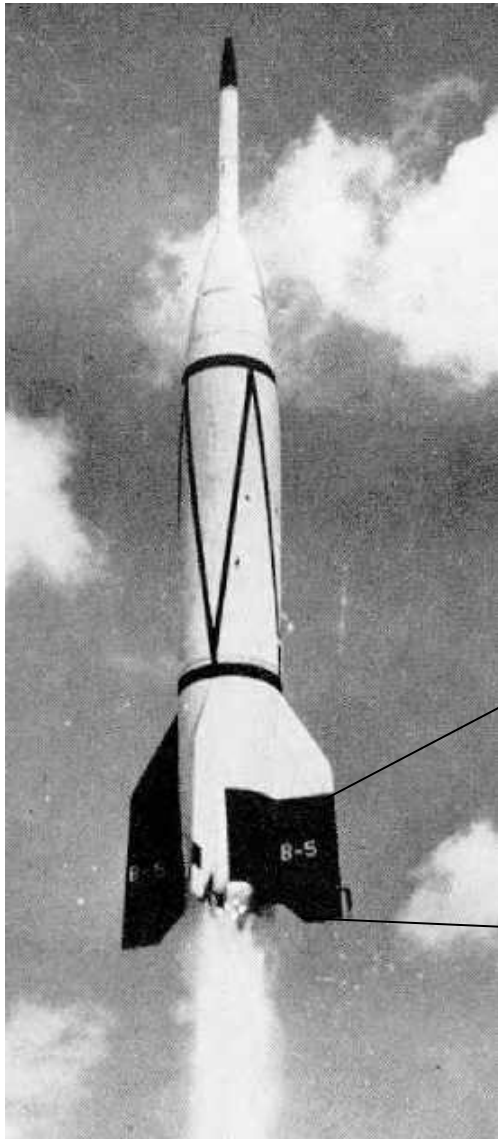
- A-4
- Titan
- Atlas
- Delta
- Mercury, Gemini, Apollo,
- Shuttle
- Future: Falcon, Taurus, ...

Sources:

<http://www.designation-systems.net/dusrm/app3/index.html>

www.astronautix.com

American A-4



**Ofen
(LOX/Alcohol)**

A-4 (1946)

US Apollo



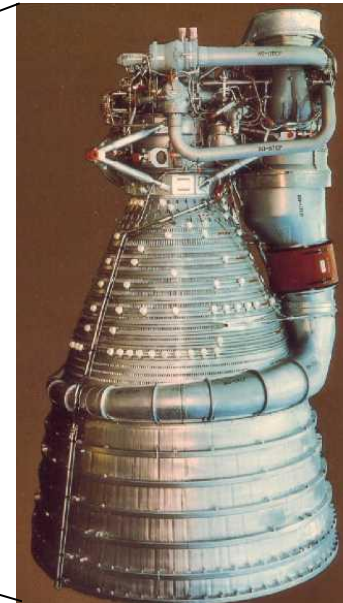
Saturn booster (1969-74)



**J-2
(LOX/LH)**



**J-2 x 5
(LOX/LH)**

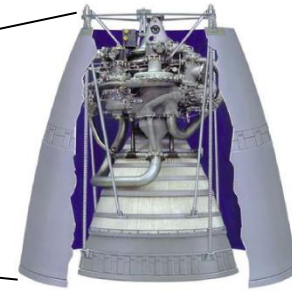


**F-1 x 5
(LOX/RP)**

US Delta IV



Delta IV (2001 – present)



**RL-10B
(LOX/LH)**



**RS-68
(LOX/LH)**

US Atlas



Atlas V (2002 – present)



**RL-10A-4
(LOX/LH)**



**RD-180
(LOX/RP)
(russian)**

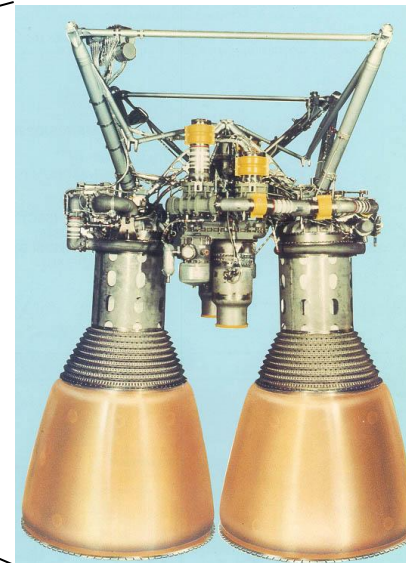
US Titan



Titan IV (1989-94)

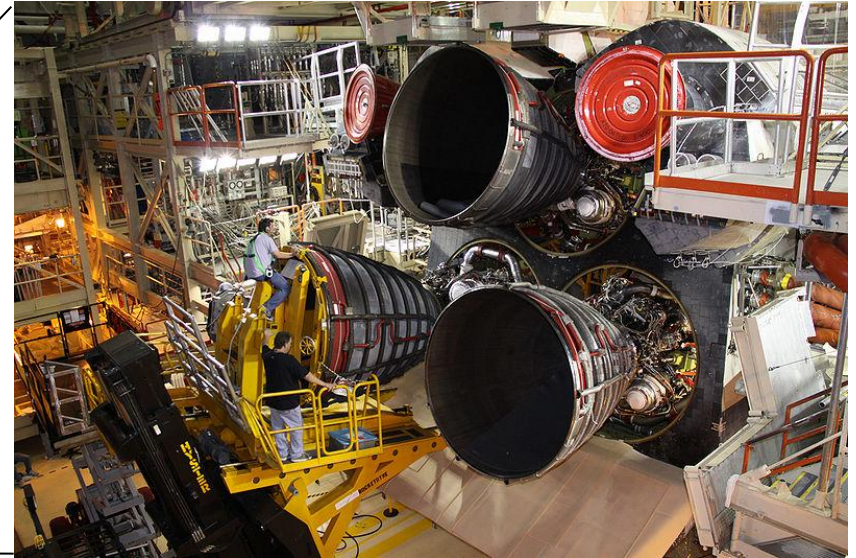


**LR-91
(N₂O₄/UDMH)**



**LR-87
(N₂O₄/UDMH)**

US Shuttle



SSME (LOX/LH)

Space Shuttle (1981-present)

US Falcon



Falcon 1 (2009-present)



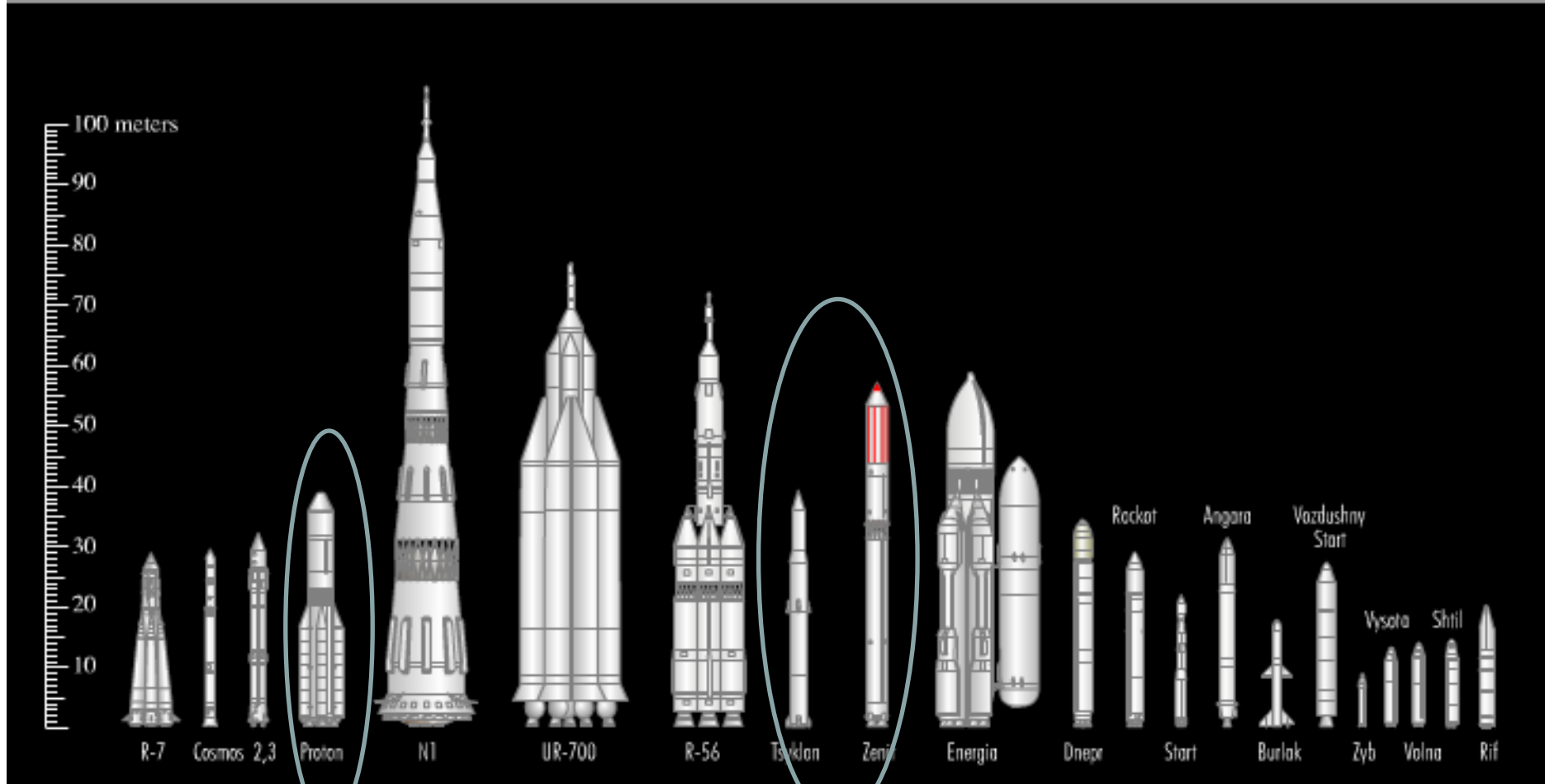
**Kestrel
(LOX/RP)**



**Merlin
(LOX/RP)**

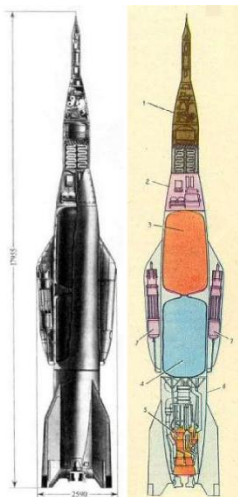
USSR/Russia/Ukraine

ROCKETS: Launchers



www.russianspaceweb.com

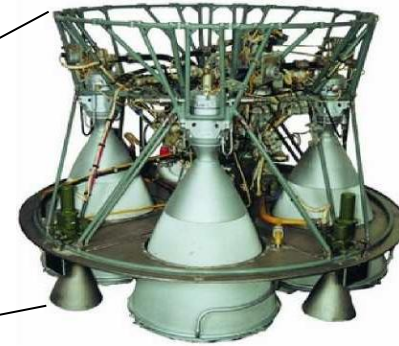
Soviet "A-4"



**RD-100
(LOX/Alcohol)**

W-1, R-1

USSR/Russian Soyuz



**RD-0110
(LOX-RP)**



**RD-107
(strap-ons
LOX-RP)**



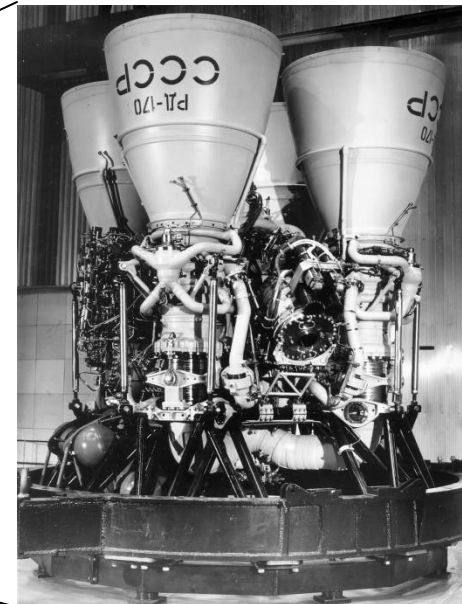
**RD-108
(core – LOX/RP)**

Soyuz (1989-94)

USSR/Ukraine Zenit



**RD-120
(LOX/RP)**



**RD-171
(LOX/RP)**

Ukraine Tsyklon

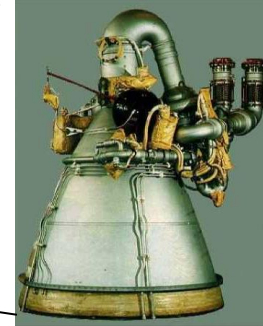


RD-262
(N₂O₄/UDMH)



RD-261
(N₂O₄/UDMH)

USSR/Russia Proton



RD-0210 x 3
(N₂O₄/UDMH)



RD-275 x 6
(N₂O₄/UDMH)

Proton

INDIA SLV's

- PSLV & variants
- GSLV & variants

India PSLV



PSLV



**LVS x 2
(4th Stage
N₂O₄/UDMH)**



**Vikas x 4
(2nd Stage,
N₂O₄/UDMH)**

India GSLV



Vikas-4
(2nd Stage,
N₂O₄/UDMH)



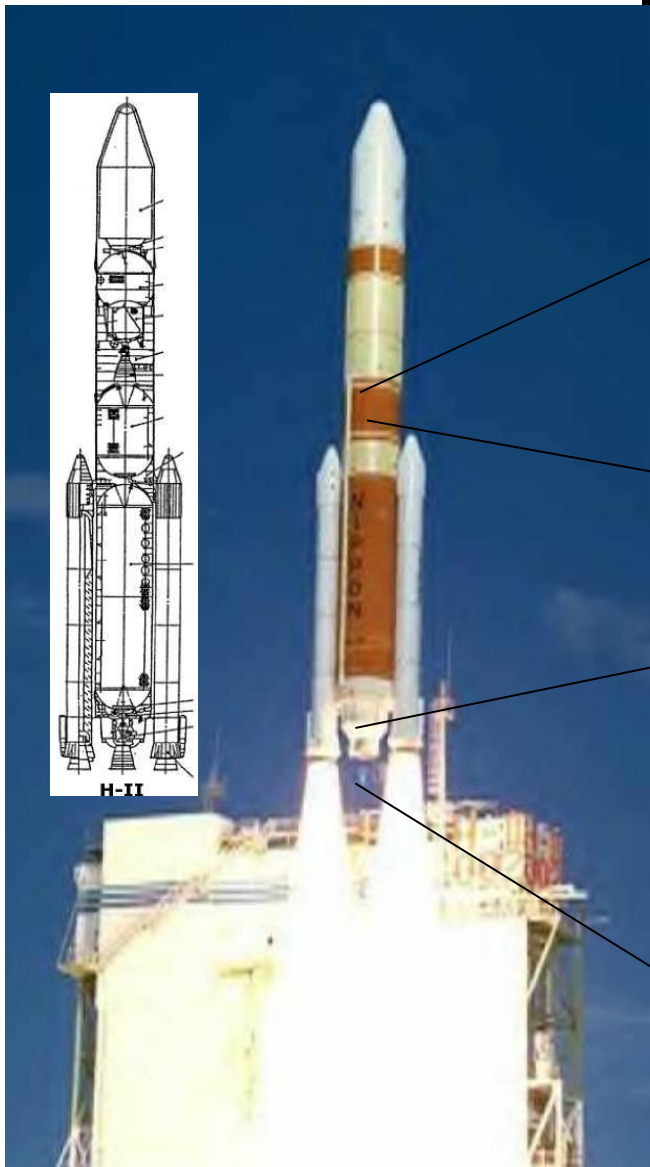
Vikas-2
(Strap-ons,
N₂O₄/UDMH)

GSLV

JAPAN SLV's

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

Japan H-II



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



**LE-7
(LOX/LH)**

Japan H-IIA/B



H-IIA (1989-94)

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



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



**LE-7A x 2
(LOX/LH)**

China "A-4"

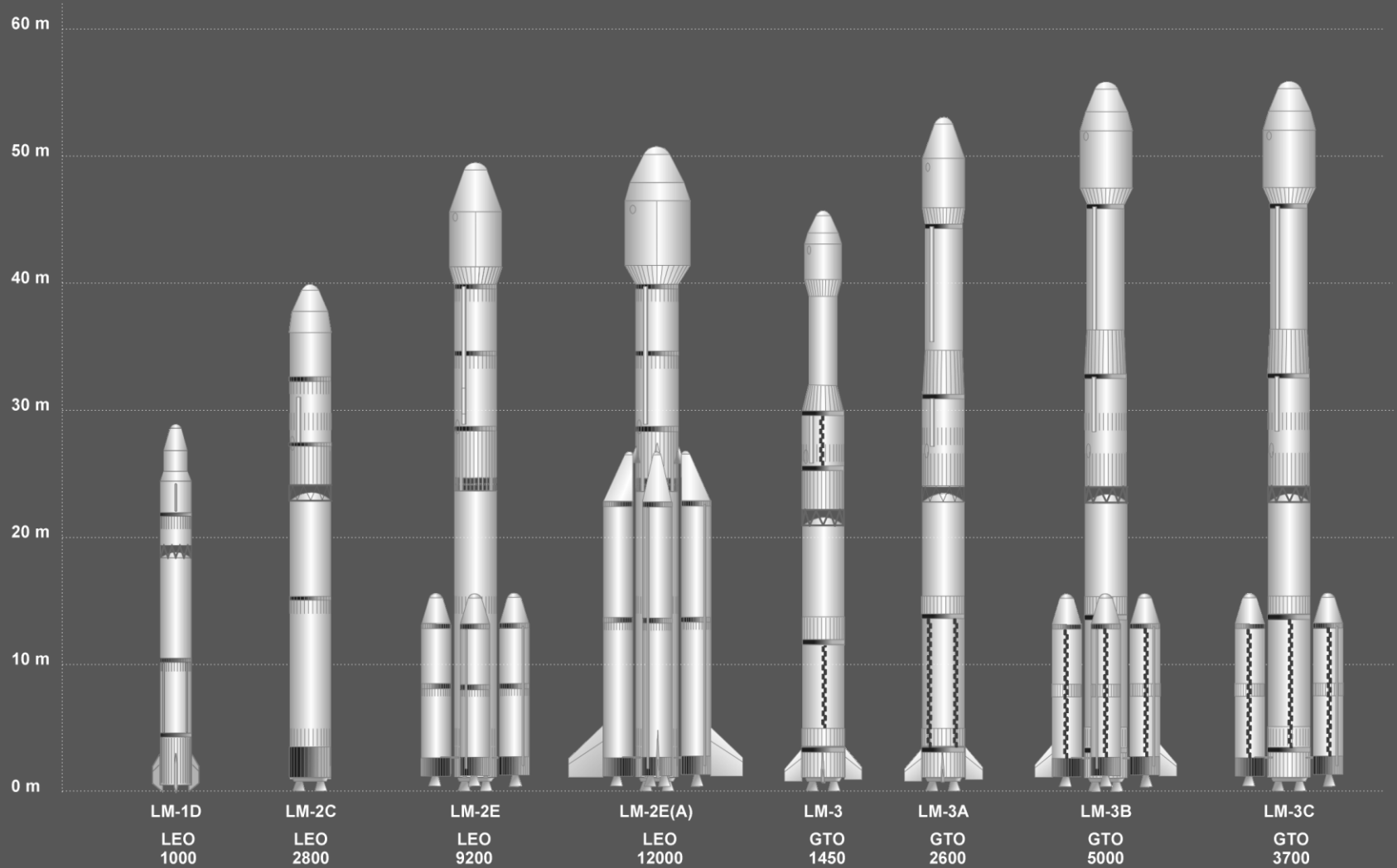


A-4 and DF-1



**USSR RD-100
(LOX/Alcohol)**

LONG MARCH SERIES



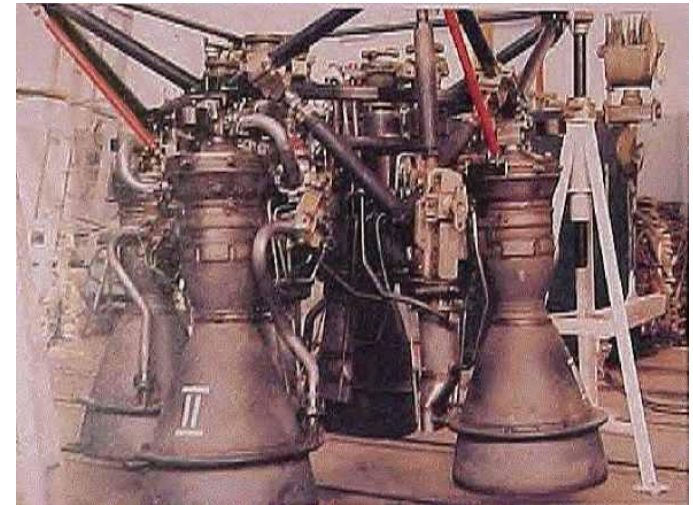
Source: www.globalsecurity.org

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

Chang Zheng - ELV



YF-24
(N2O4/UDMH)



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

Chang Zheng – Human Rated



YF-26
(N2O4/UDMH)

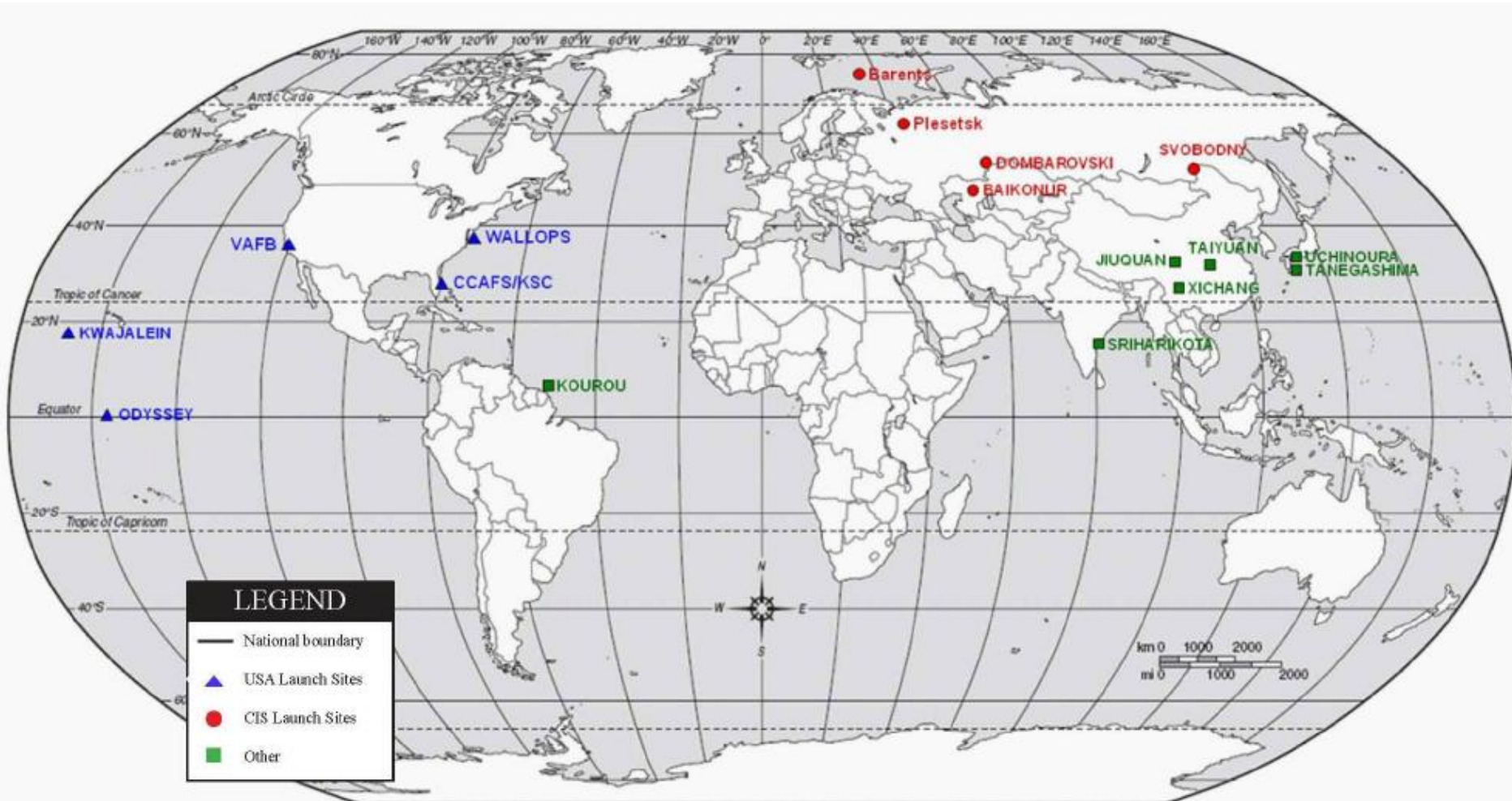


YF-21 = YF-20 x 4
(N2O4/UDMH)

YF-25
(N2O4/UDMH)

CZ-2F

Launch Sites



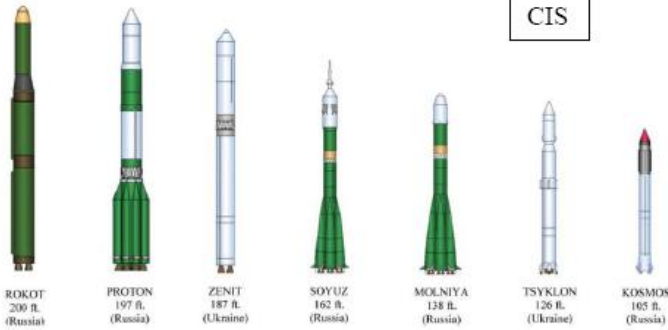
Source:

AIAA Paper 2010-974, Rahman, Keim, and Zeender

IAC Paper IAC-09-D1.5.1, Tomei and Chang

Launch Activity

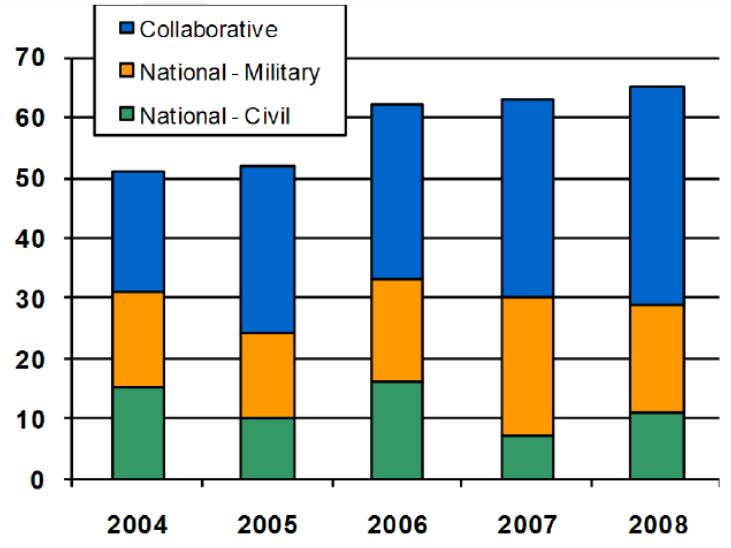
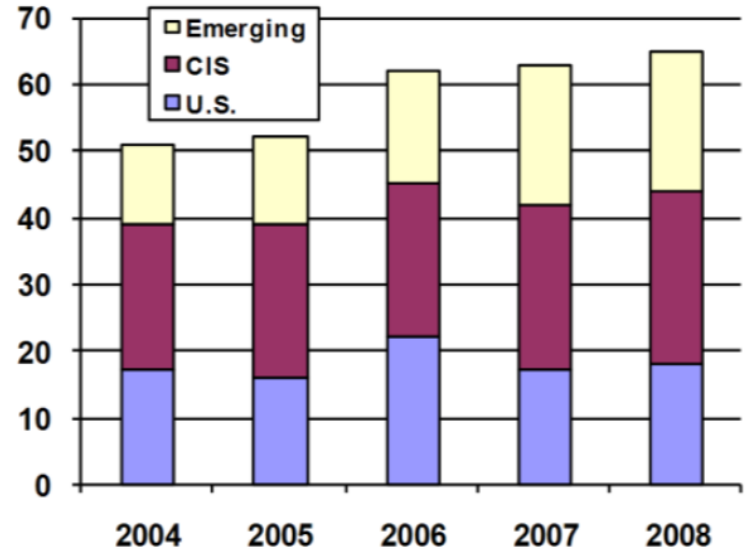
CIS



USA

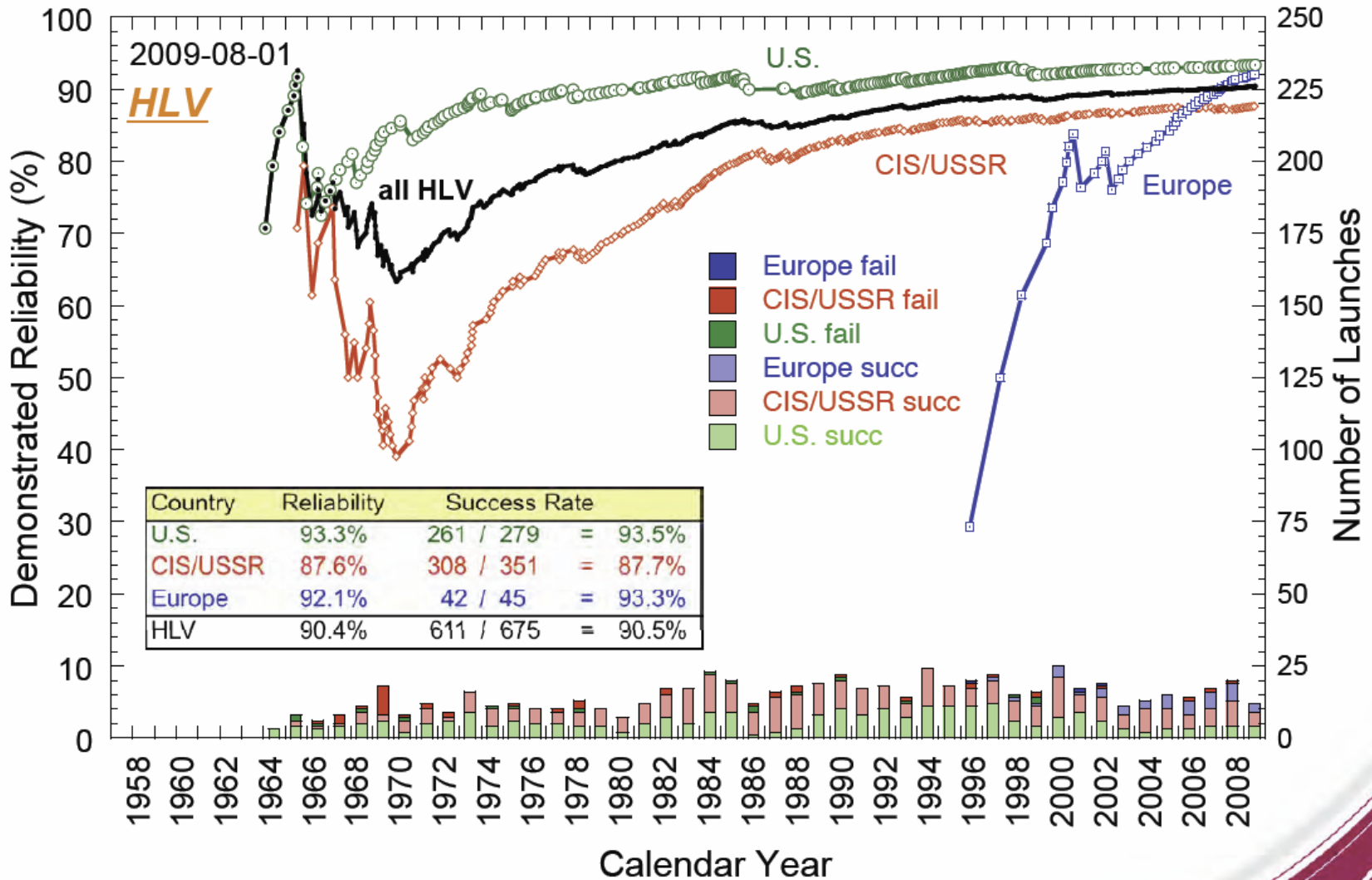


Emerging



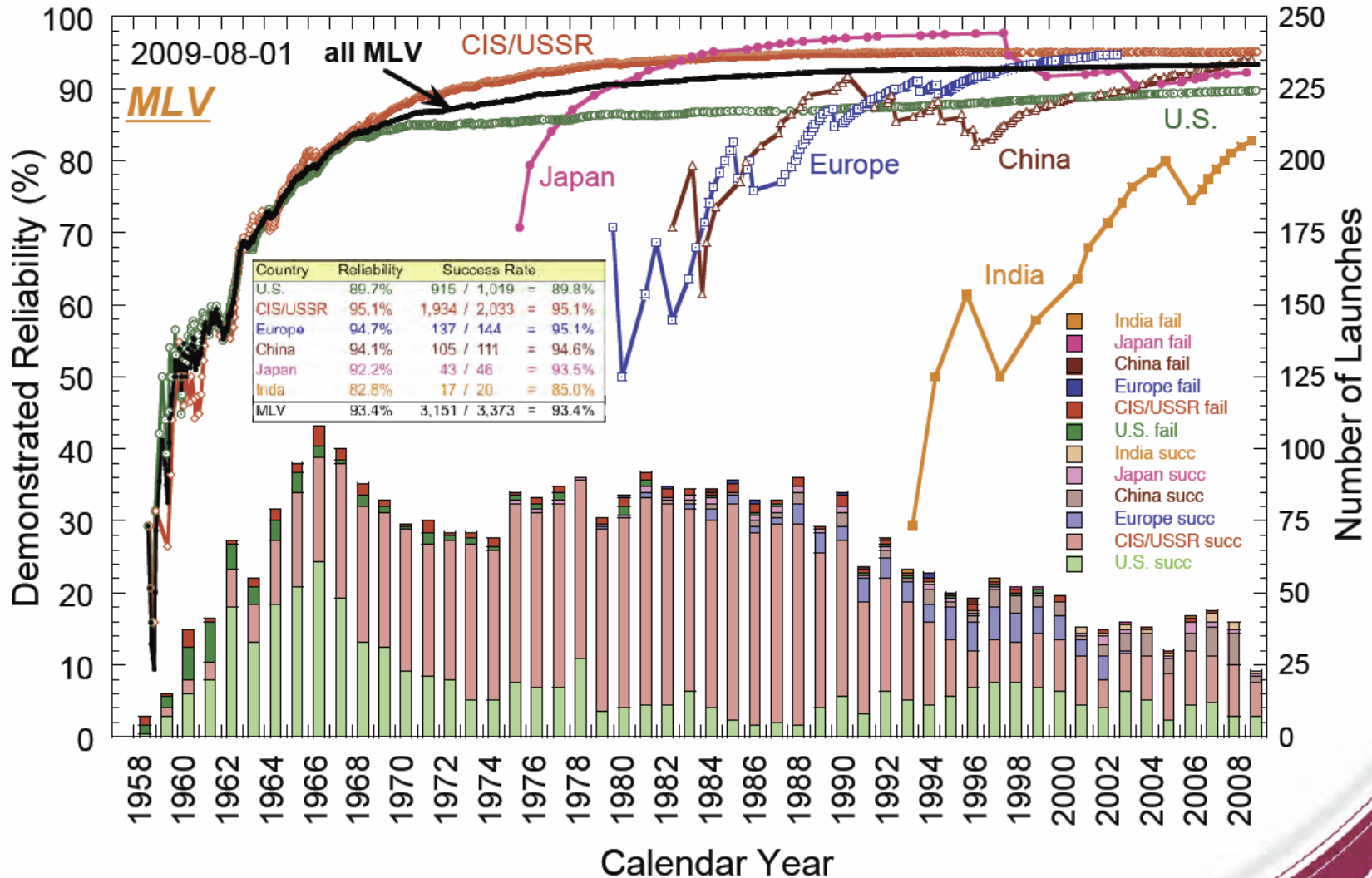
HLV Reliability for Different Countries

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.

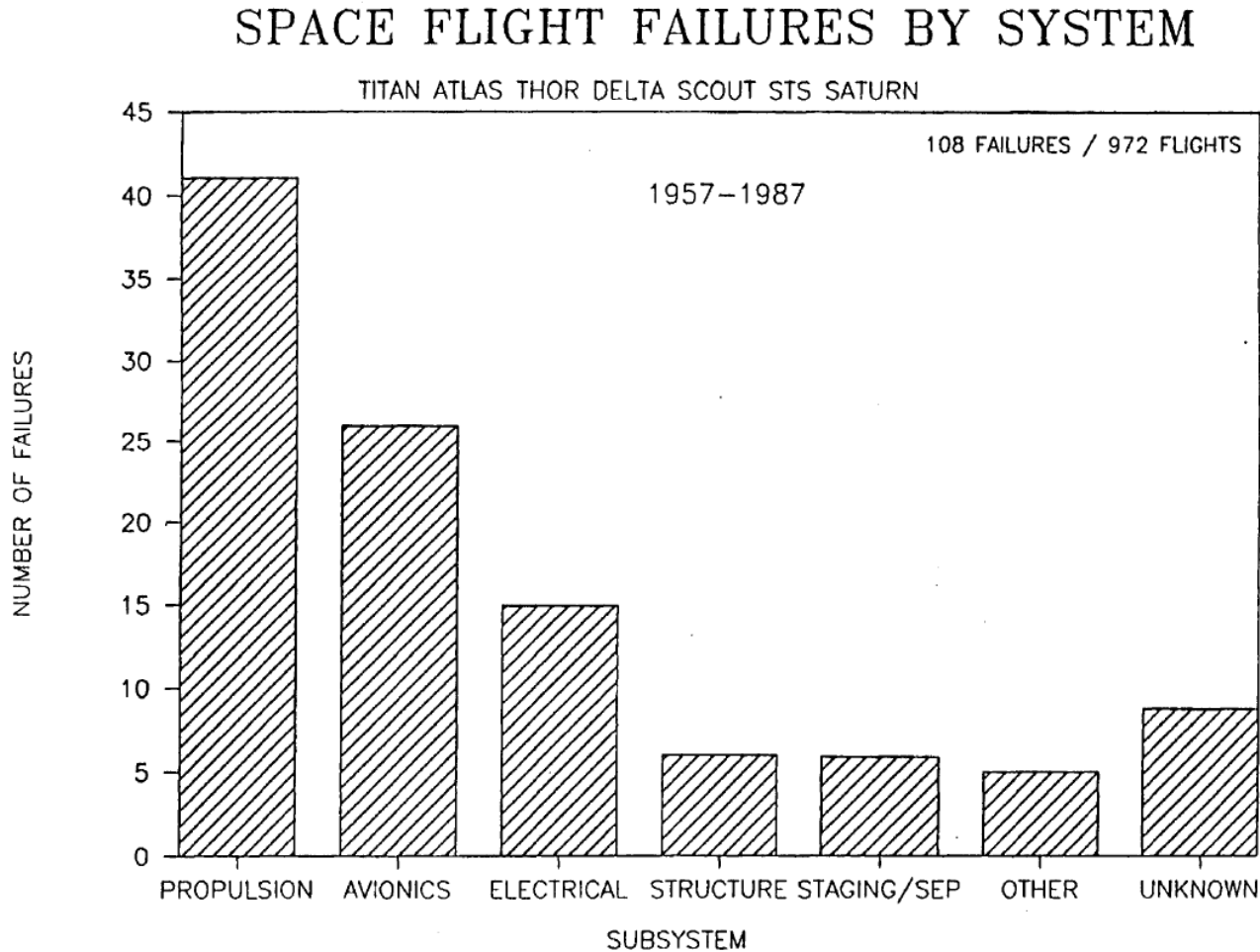


MLV Reliability for Different Countries

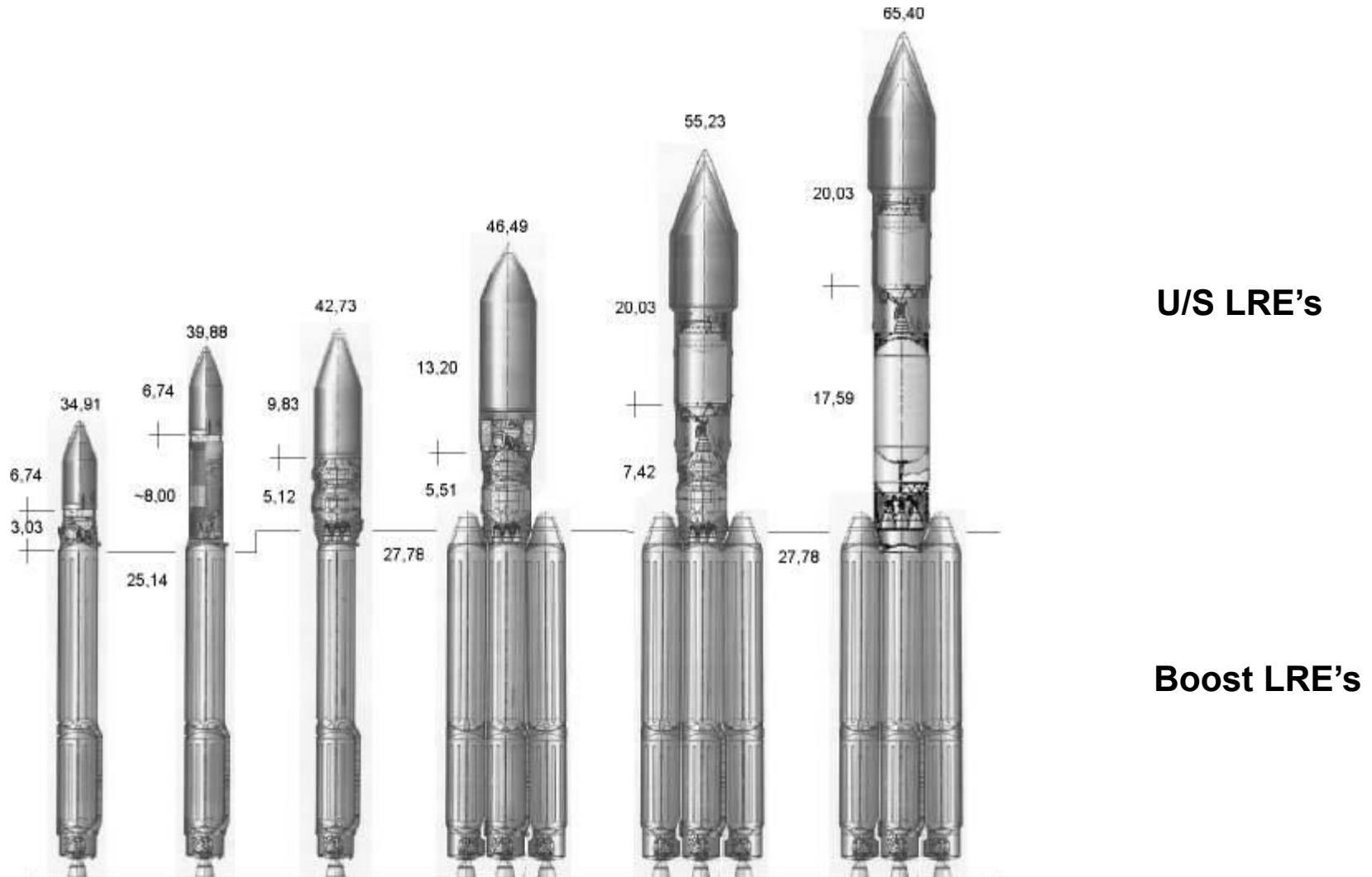
Source: IAC-09-D1.5.1 ... "51 Years of Space Launches and Failures" E. Joe Tomei and I-Shih Chang, The Aerospace Corporation, U.S.A.



Demonstrated Reliability - Failure Causes (US) -



What's Next - Russia



Angara Series

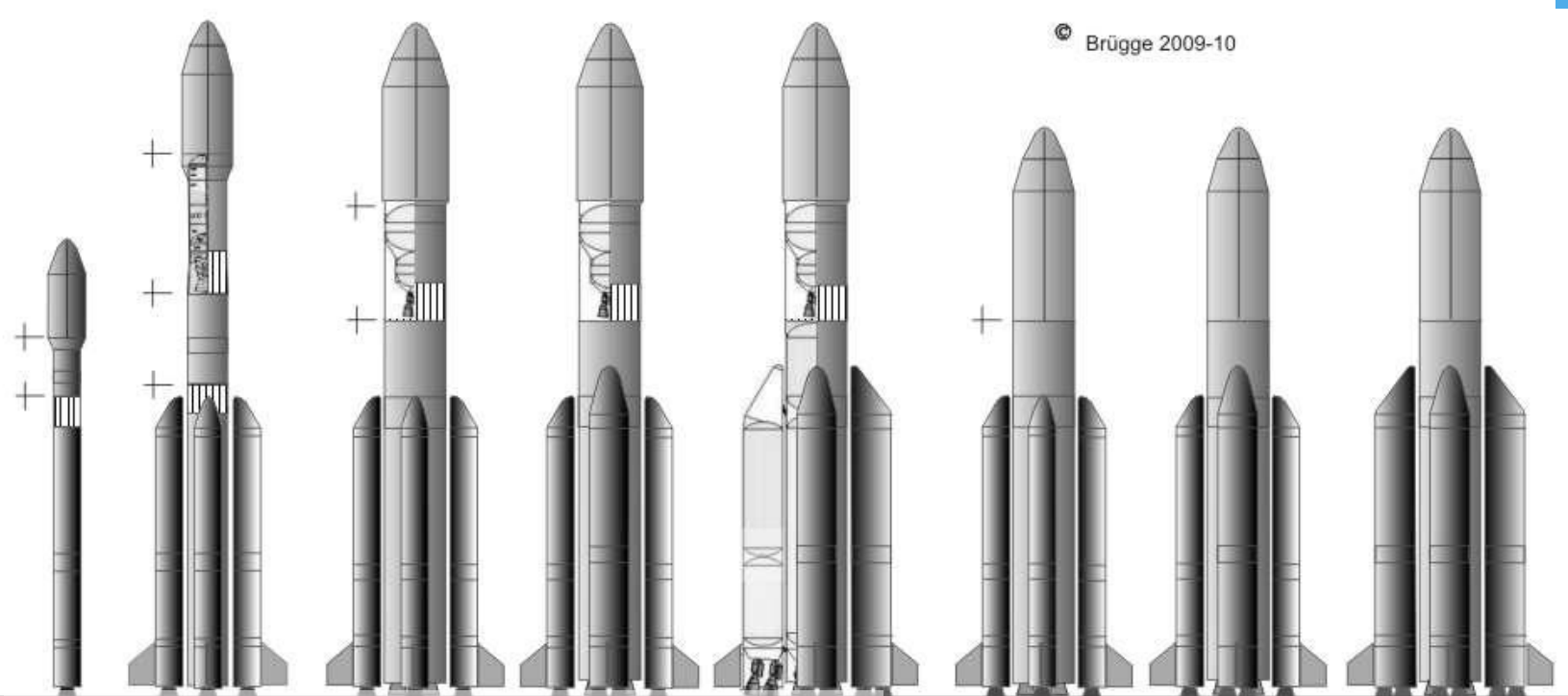
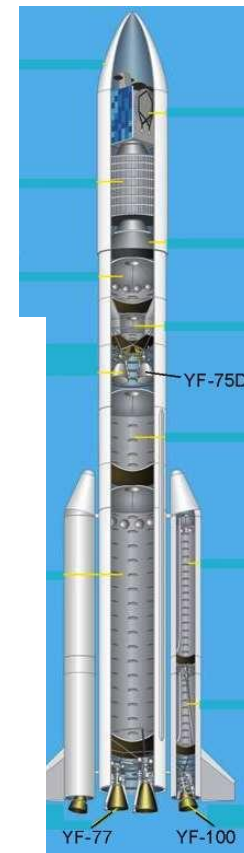
RELEASED - Printed documents may be obsolete; validate prior to use.

What's Next - China

YF-77
(LOX/LH)



YF-100
(LOX/RP1)



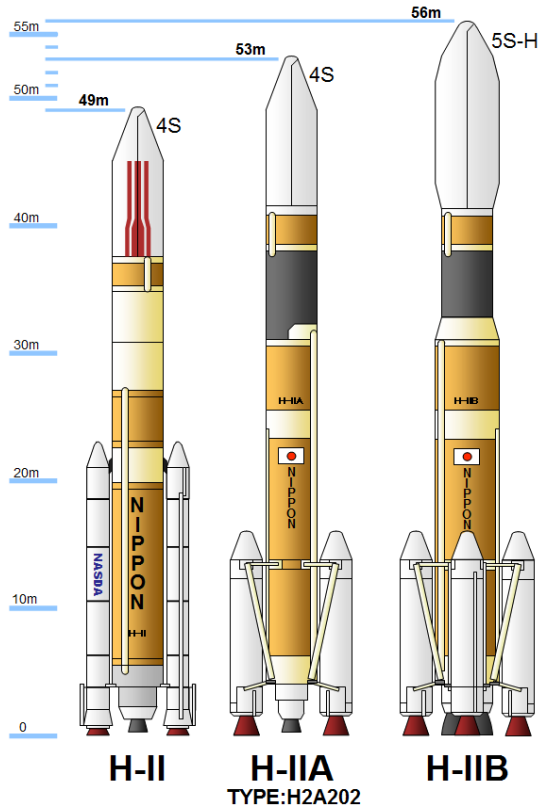
What's Next - ESA



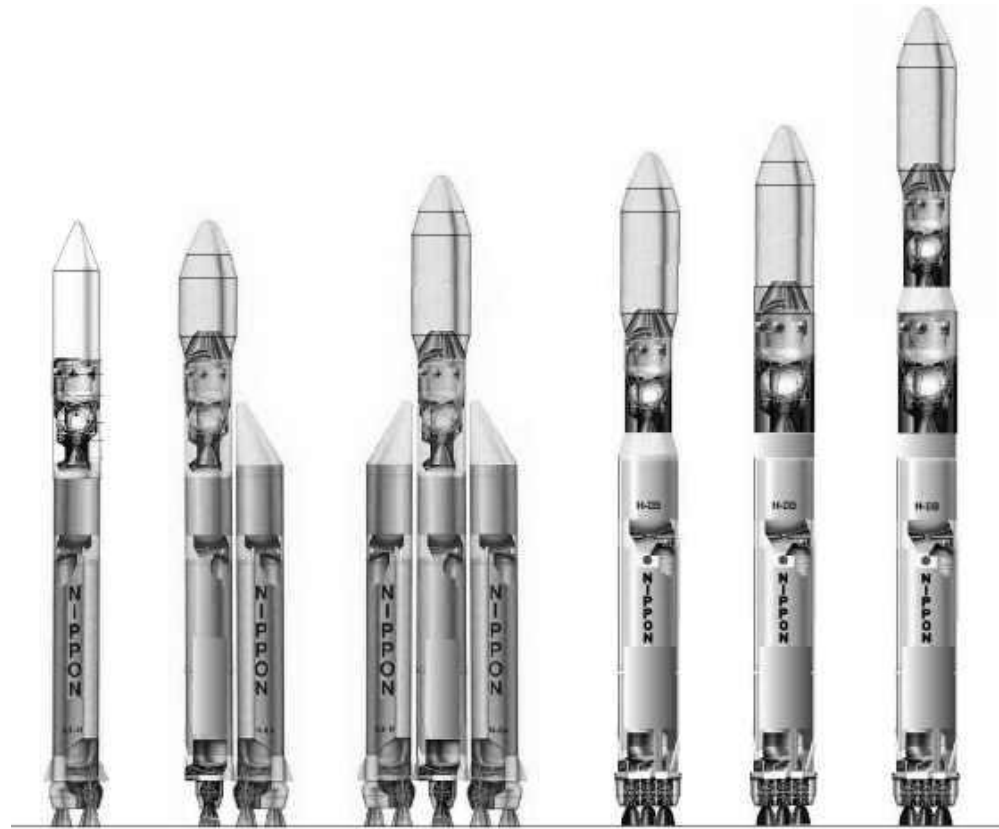
RELEASED - Printed documents may be obsolete; validate prior to use.

Vega + Soyuz + Ariane = Fleet

What's Next - Japan



H-II Series



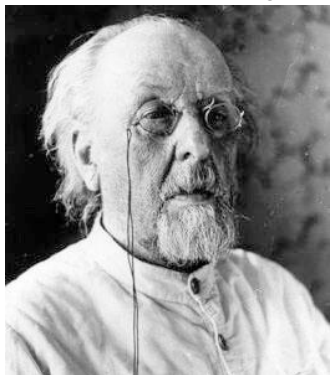
H-X Series



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

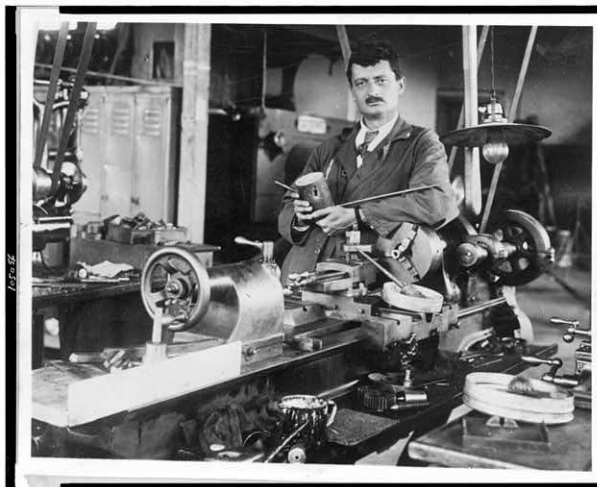
Tsiolkovsky



Goddard



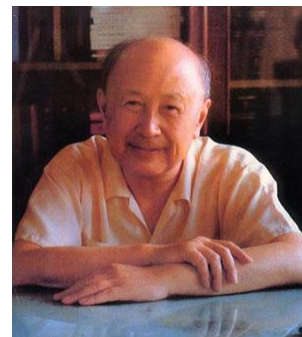
Oberth



Korolyov



Von Braun



Tsien



Abdul Kalam



Yuri

... and many more!