



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)

A-4 (1946)

Source: www.b14643.de/Spacerockets_1

Ofen-B
(LOX/Alcohol)

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.

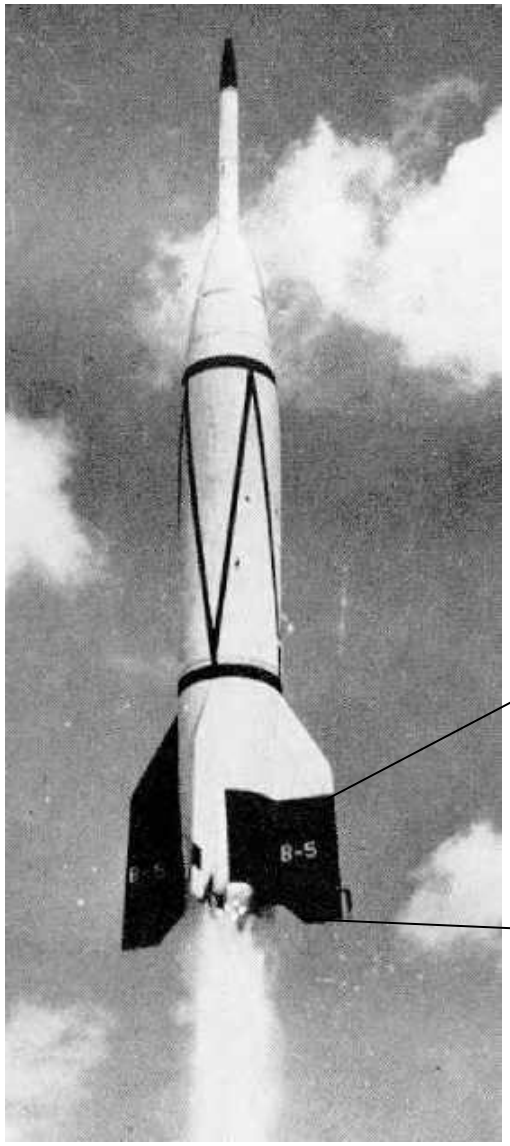
Discuss Liquid Rocket Engine propelled vehicles
Solid rocket based heritage not elaborated here.

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)

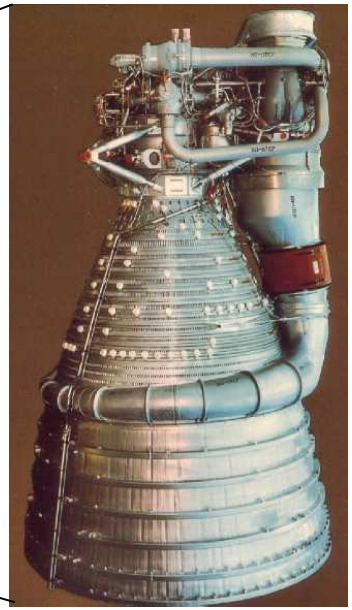
Ofen
(LOX/Alcohol)

US Apollo

Saturn booster (1969-74)

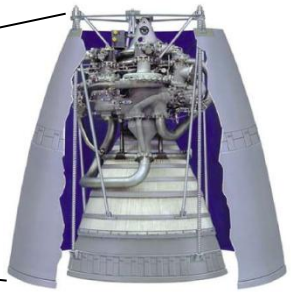
J-2
(LOX/LH)

J-2 x 5
(LOX/LH



F-1 x 5
(LOX/RP)

US Delta IV



RL-10B
(LOX/LH)

RS-68
(LOX/LH)

Delta IV (2001 – present)

US Atlas

RL-10A-4
(LOX/LH)

RD-180
(LOX/RP)
(russian)

Atlas V (2002 – present)

US Titan

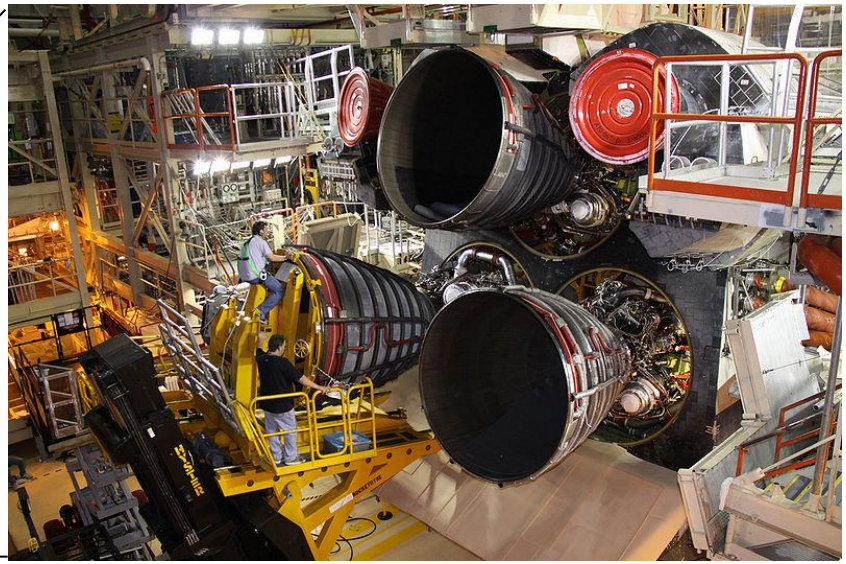
Titan IV (1989-94)

LR-91
(N2O4/UDMH)

LR-87
(N2O4/UDMH)

US Shuttle

Space Shuttle (1981-present)



SSME (LOX/LH)

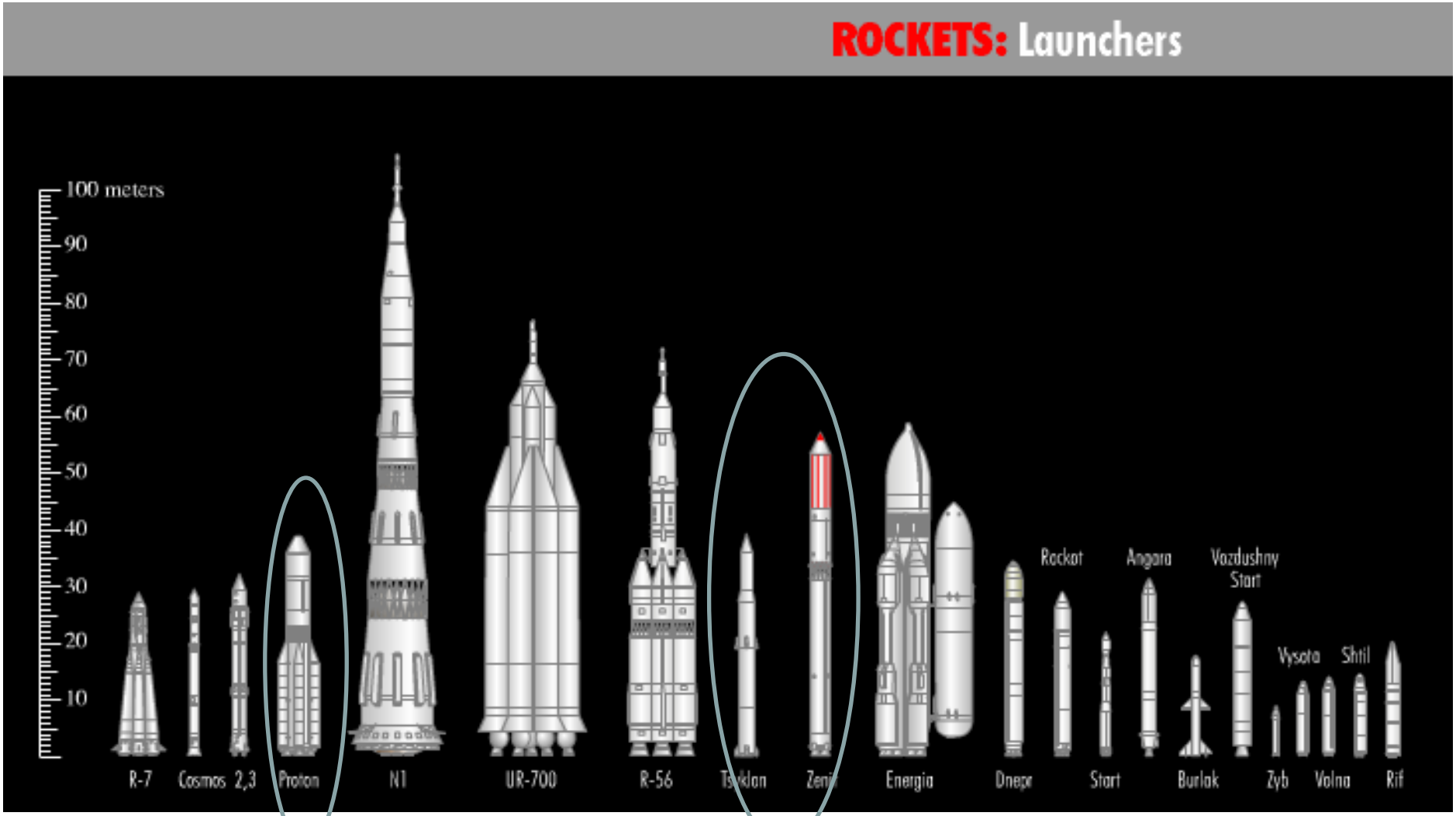
US Falcon

Falcon 1 (2009-present)

Kestrel (LOX/RP)

Merlin (LOX/RP)

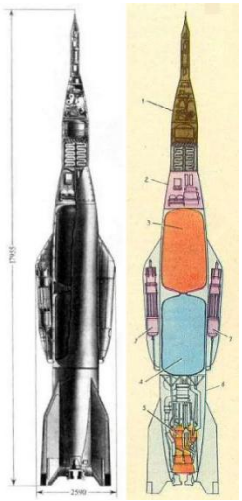
USSR/Russia/Ukraine



www.russianspaceweb.com

www.b14643.de/spacerockets_1

Soviet “A-4”



RD-100
(LOX/Alcohol)

W-1, R-1

USSR/Russian Soyuz

Soyuz (1989-94)

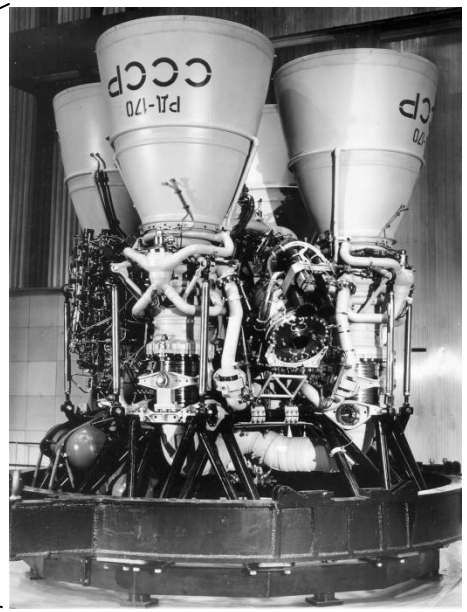
RD-0110 (LOX-RP)

RD-107 (strap-ons LOX-RP)

RD-108 (core – LOX/RP)

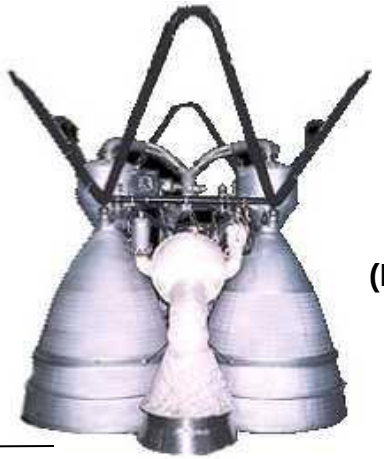
USSR/Ukraine Zenit

RD-120
(LOX/RP)



RD-171
(LOX/RP)

Ukraine Tsyklon



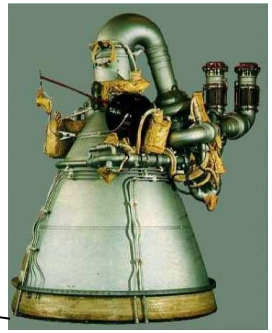
RD-262
(N2O4/UDMH)

RD-261
(N2O4/UDMH)

Tsyklon (1980-present)

USSR/Russia Proton

Proton



RD-0210 x 3
(N2O4/UDMH)

RD-275 x 6
(N2O4/UDMH)

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)

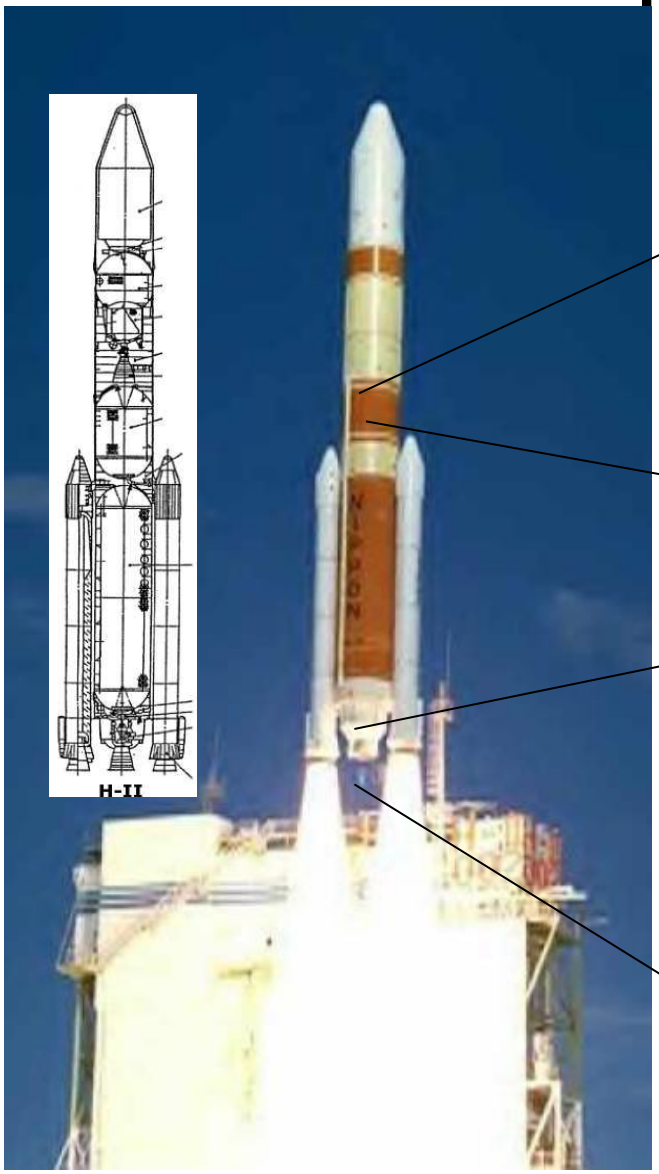
Vikas-2 (Strap-ons, N2O4/UDMH)

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)

LE-5B
(LOX/LH)

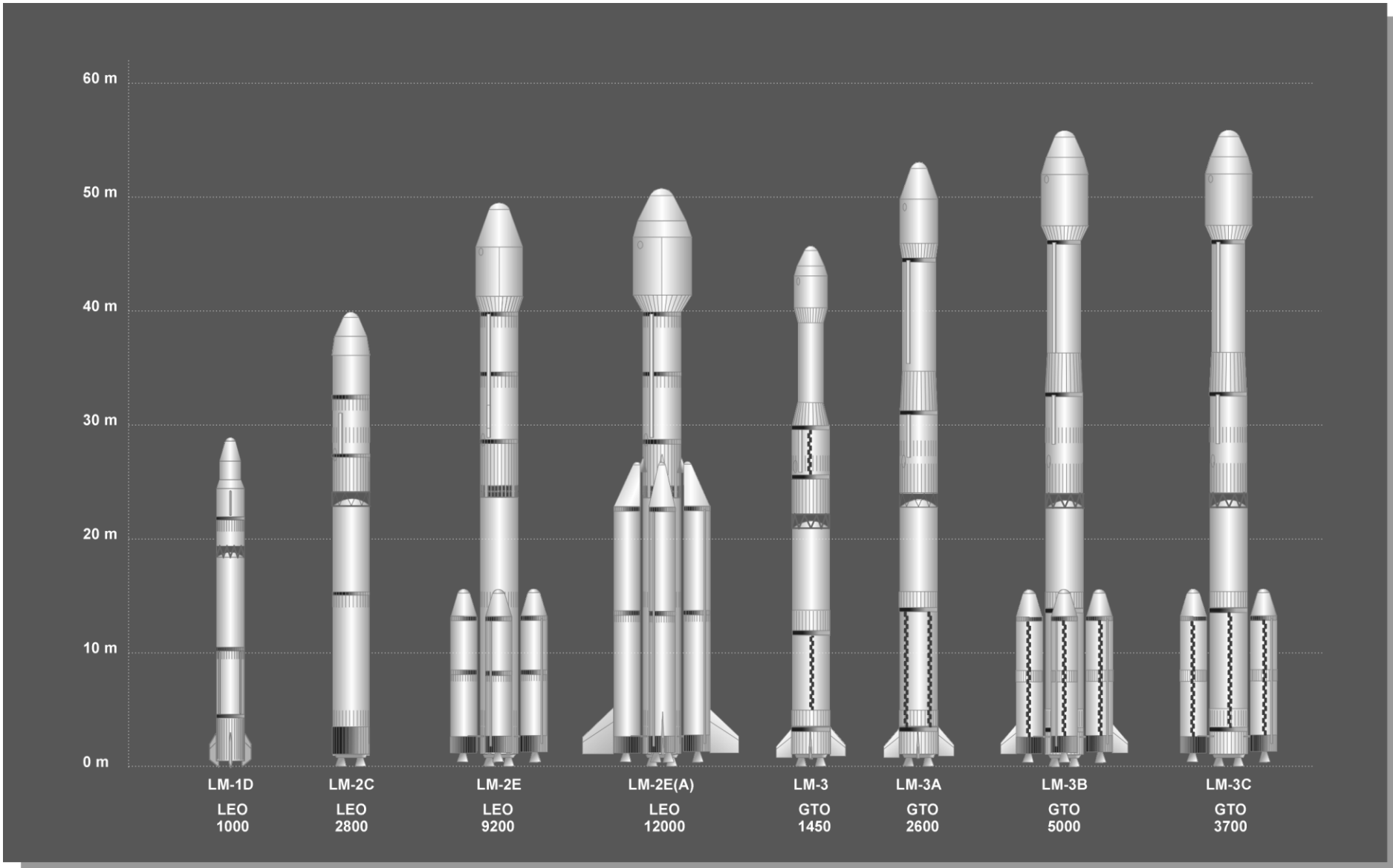
LE-7A x 2
(LOX/LH)

China “A-4”

USSR RD-100
(LOX/Alcohol)

A-4 and DF-1

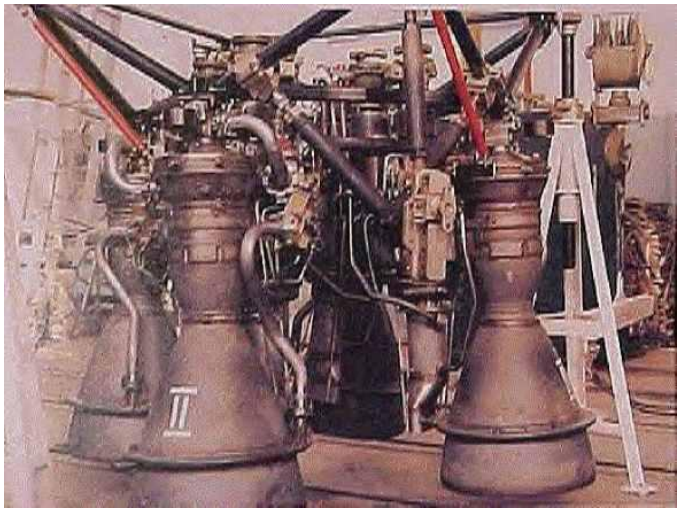
LONG MARCH SERIES



Source: www.globalsecurity.org

Chang Zheng - ELV

YF-24
(N2O4/UDMH)



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

CZ-4 series

Chang Zheng – Human Rated

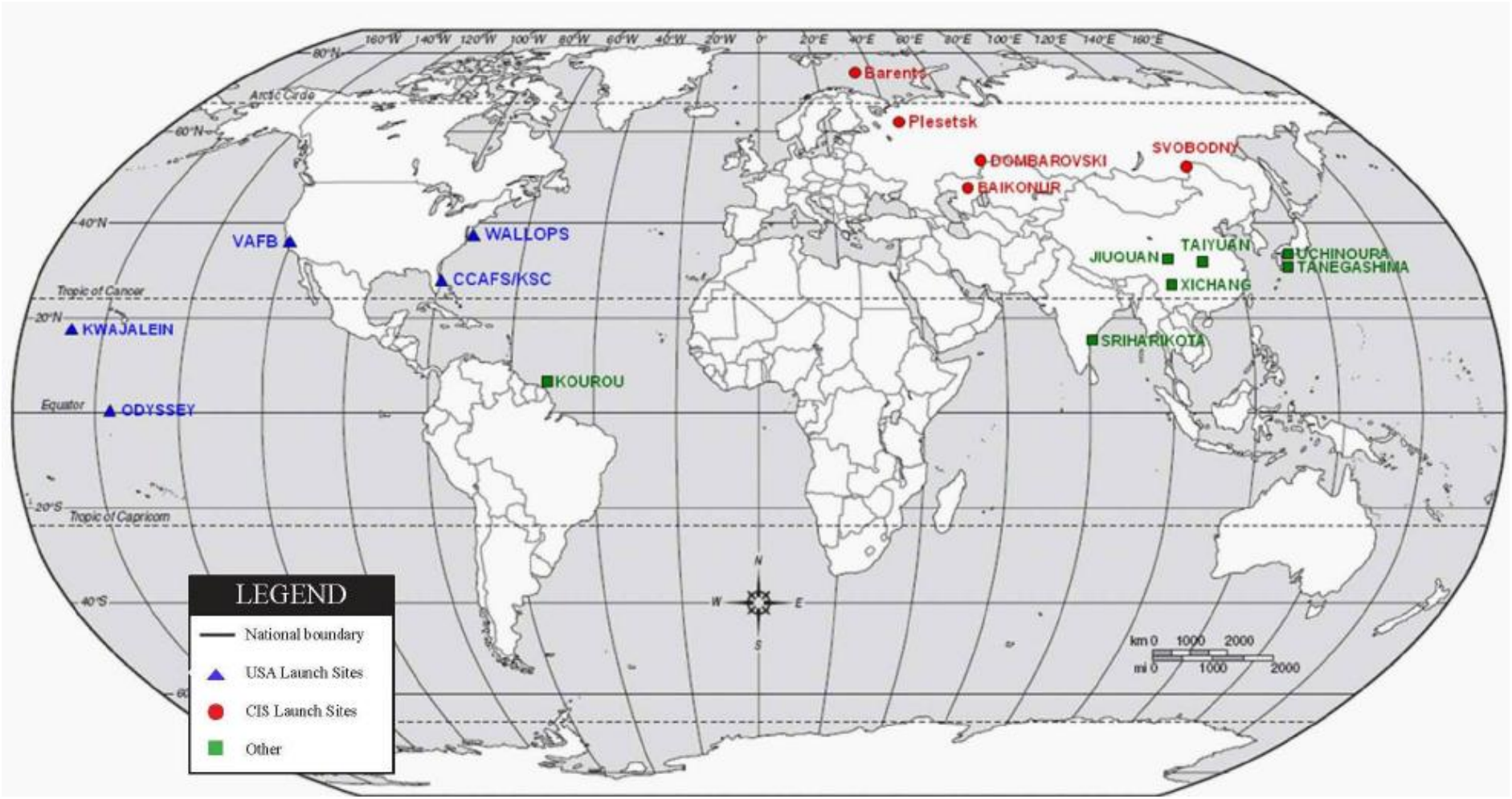
CZ-2F

YF-26
(N2O4/UDMH)

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

YF-25
(N2O4/UDMH)

Launch Sites

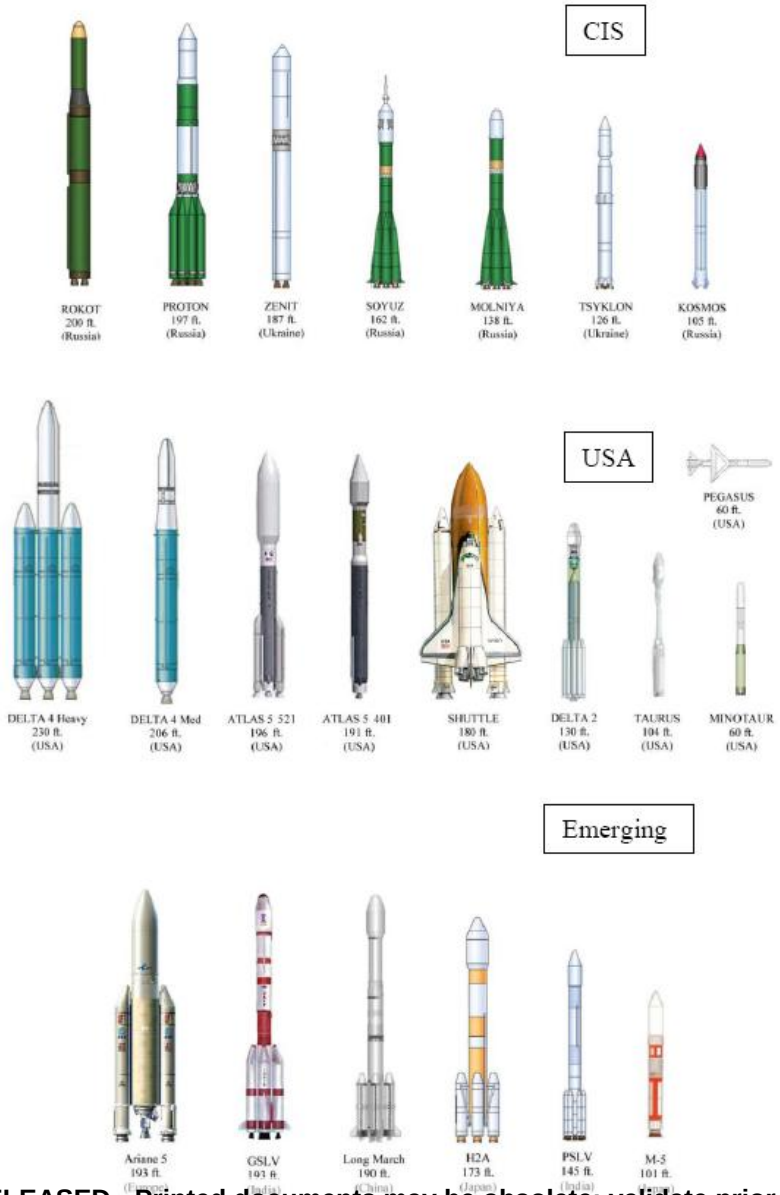


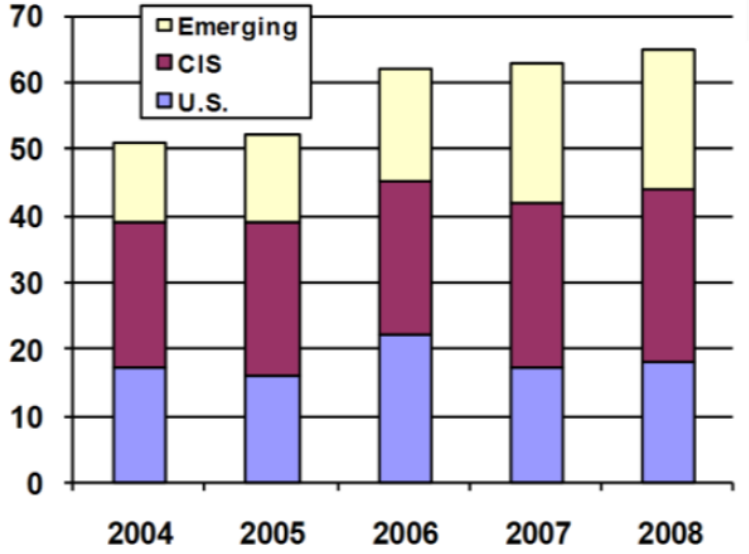
Source:

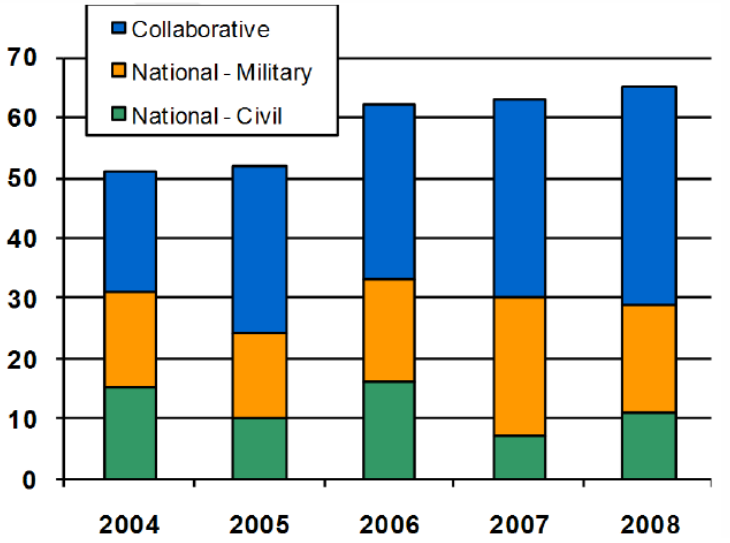
AIAA Paper 2010-974, Rahman, Keim, and Zeender

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

Launch Activity

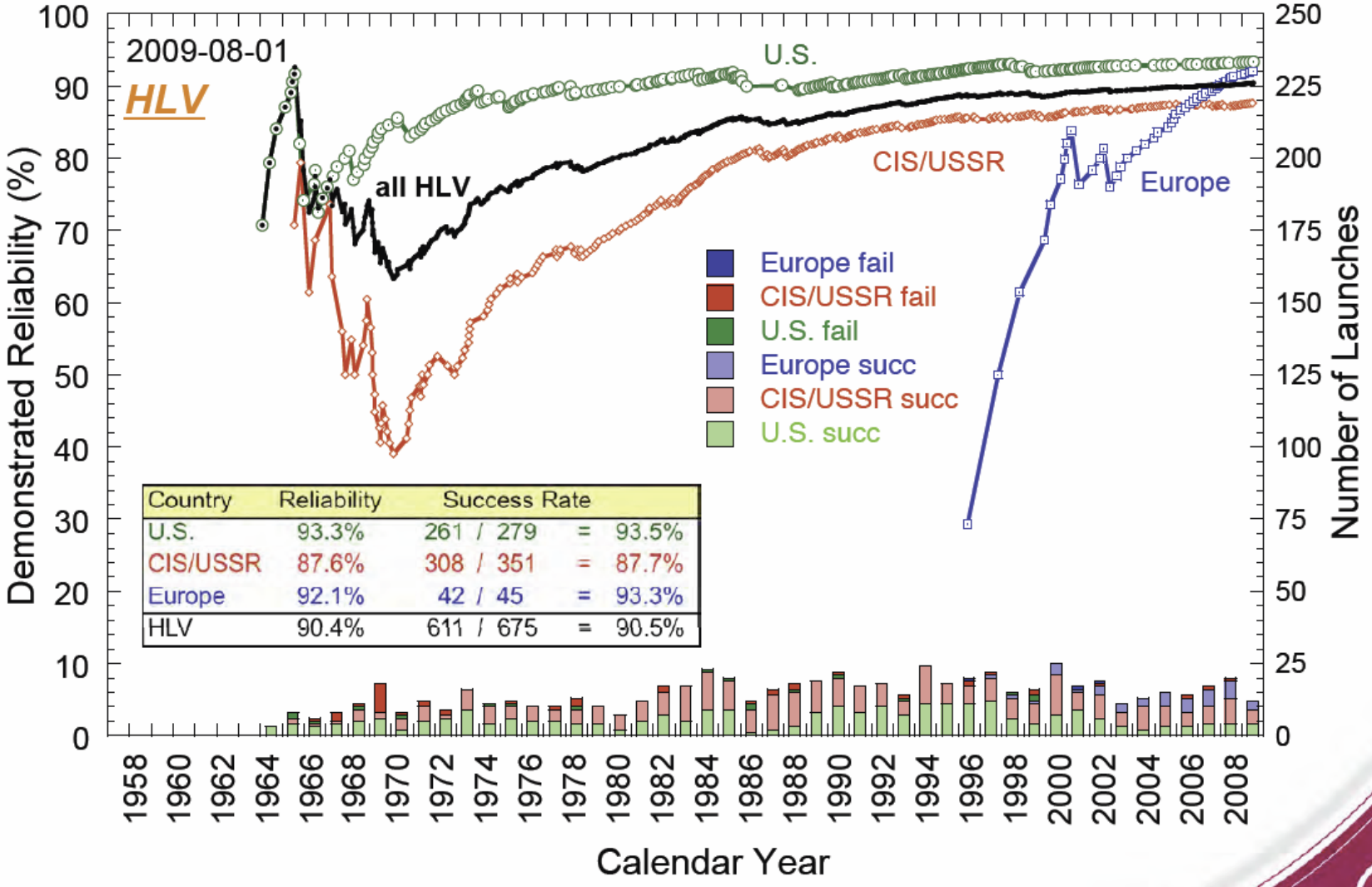






HLV Reliability for Different Countries

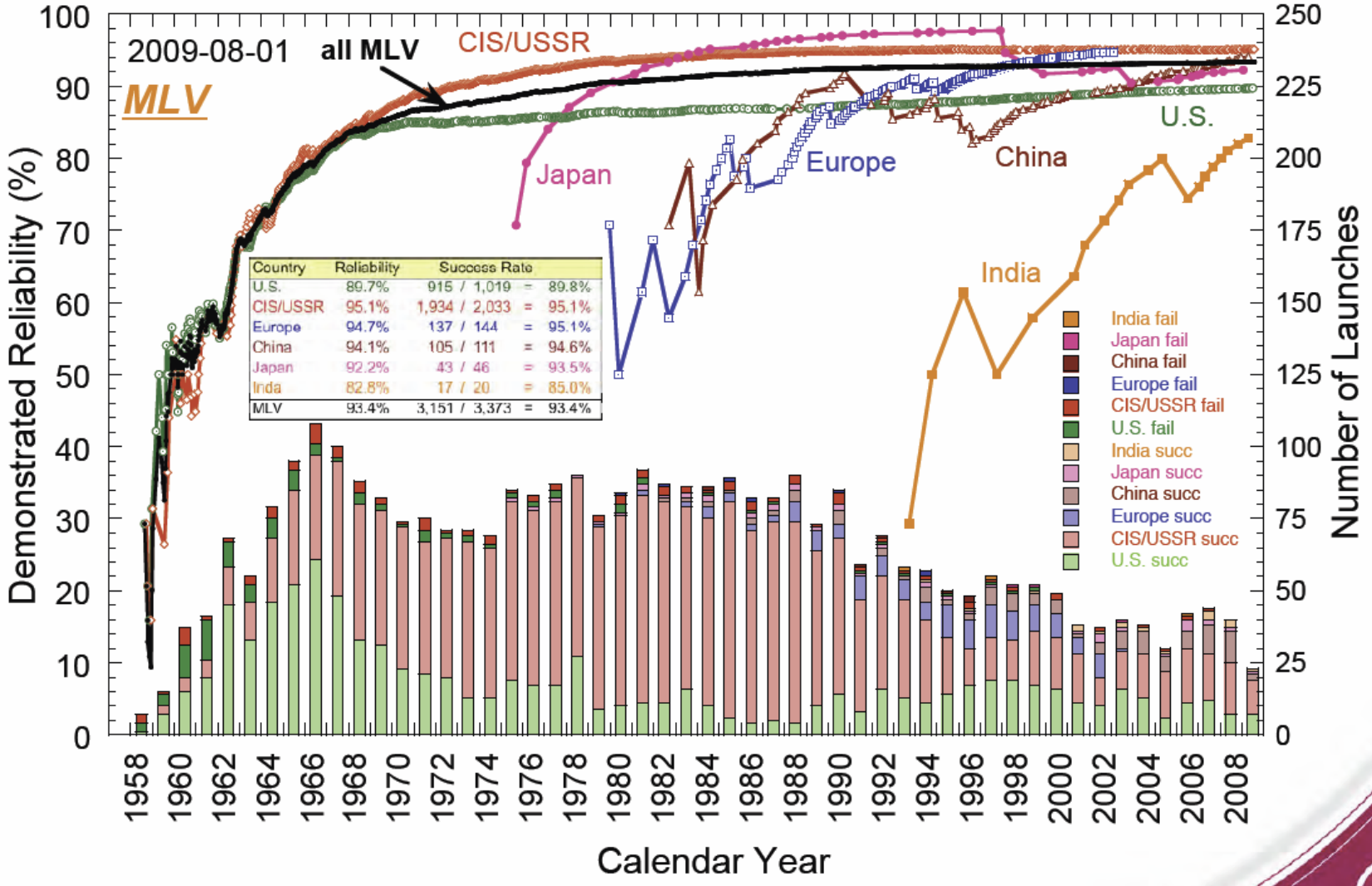
Source: IAC-09-D1.5.1 … "51 Years of Space Launches and Failures" E. Joe Tomei and I-Shih Chang, The Aerospace Corporation, U.S.A.



Country	Reliability	Success Rate		
U.S.	93.3%	261 / 279	=	93.5%
CIS/USSR	87.6%	308 / 351	=	87.7%
Europe	92.1%	42 / 45	=	93.3%
HLV	90.4%	611 / 675	=	90.5%

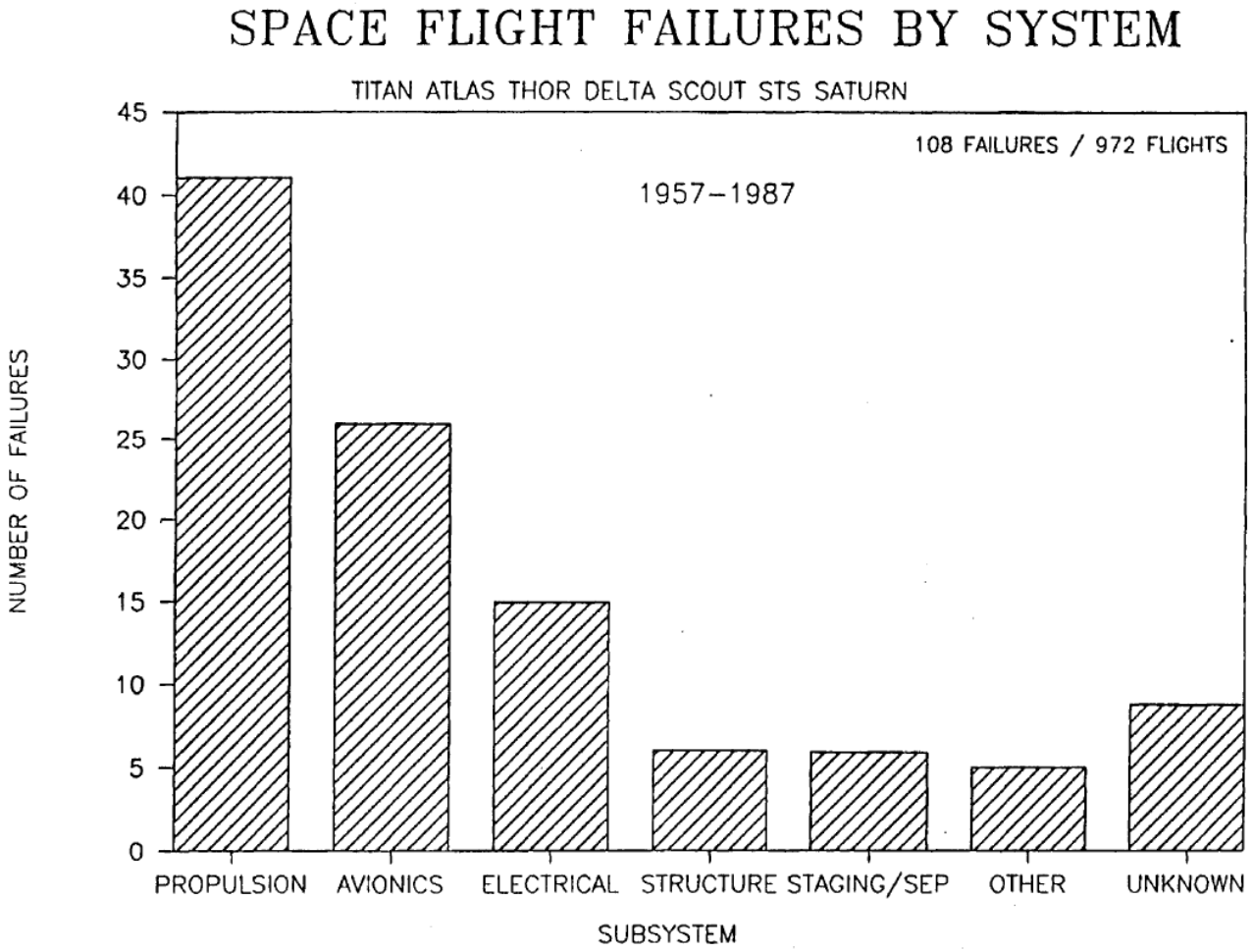
MLV Reliability for Different Countries

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.

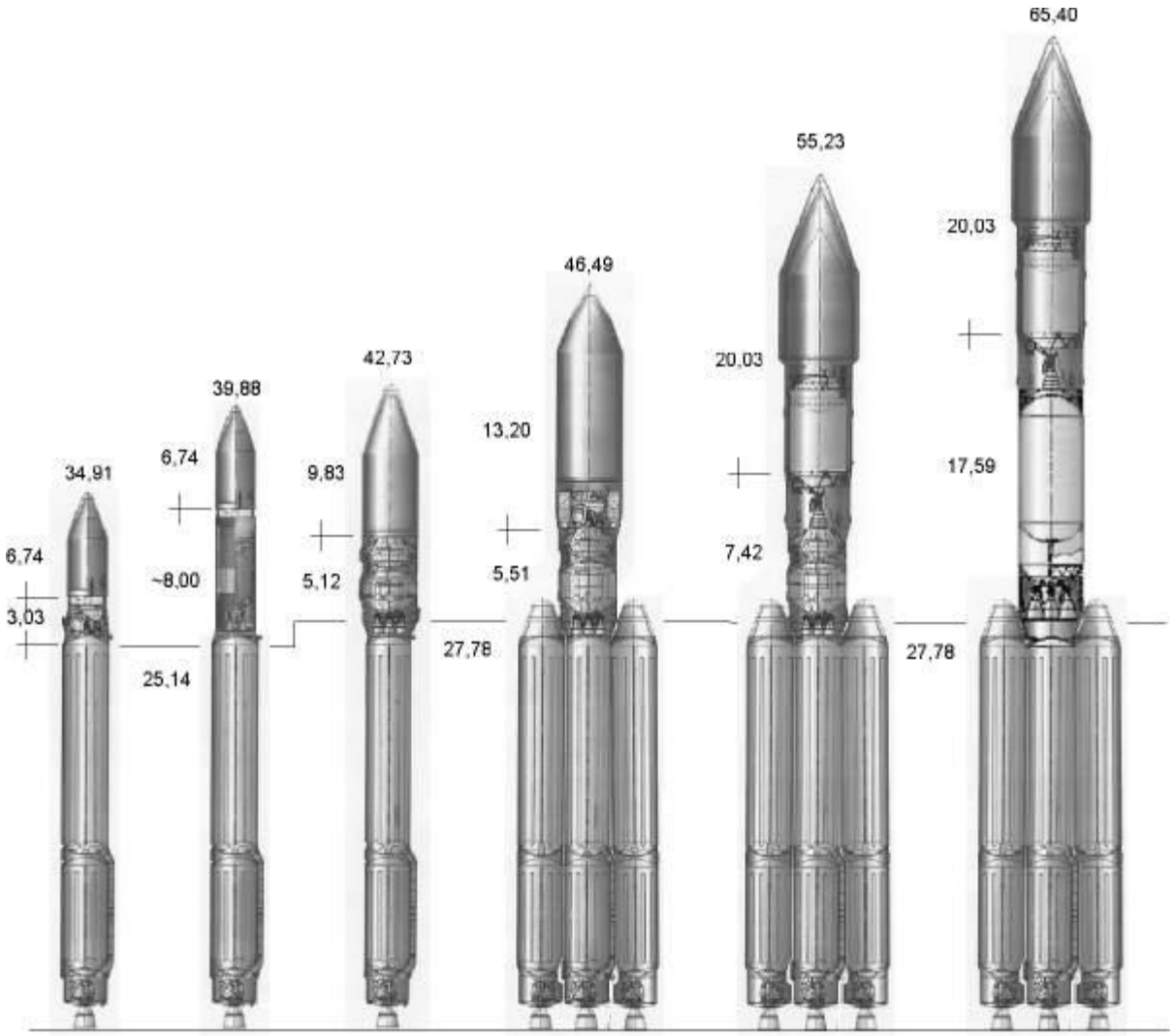


Country	Reliability	Success Rate		
U.S.	89.7%	915 / 1,019	=	89.8%
CIS/USSR	95.1%	1,934 / 2,033	=	95.1%
Europe	94.7%	137 / 144	=	95.1%
China	94.1%	105 / 111	=	94.6%
Japan	92.2%	43 / 46	=	93.5%
Inda	82.8%	17 / 20	=	85.0%
MLV	93.4%	3,151 / 3,373	=	93.4%

Demonstrated Reliability
- Failure Causes (US) -



What's Next - Russia



U/S LRE's

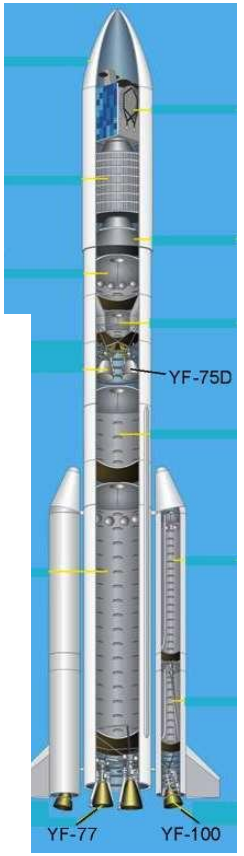
Boost LRE's

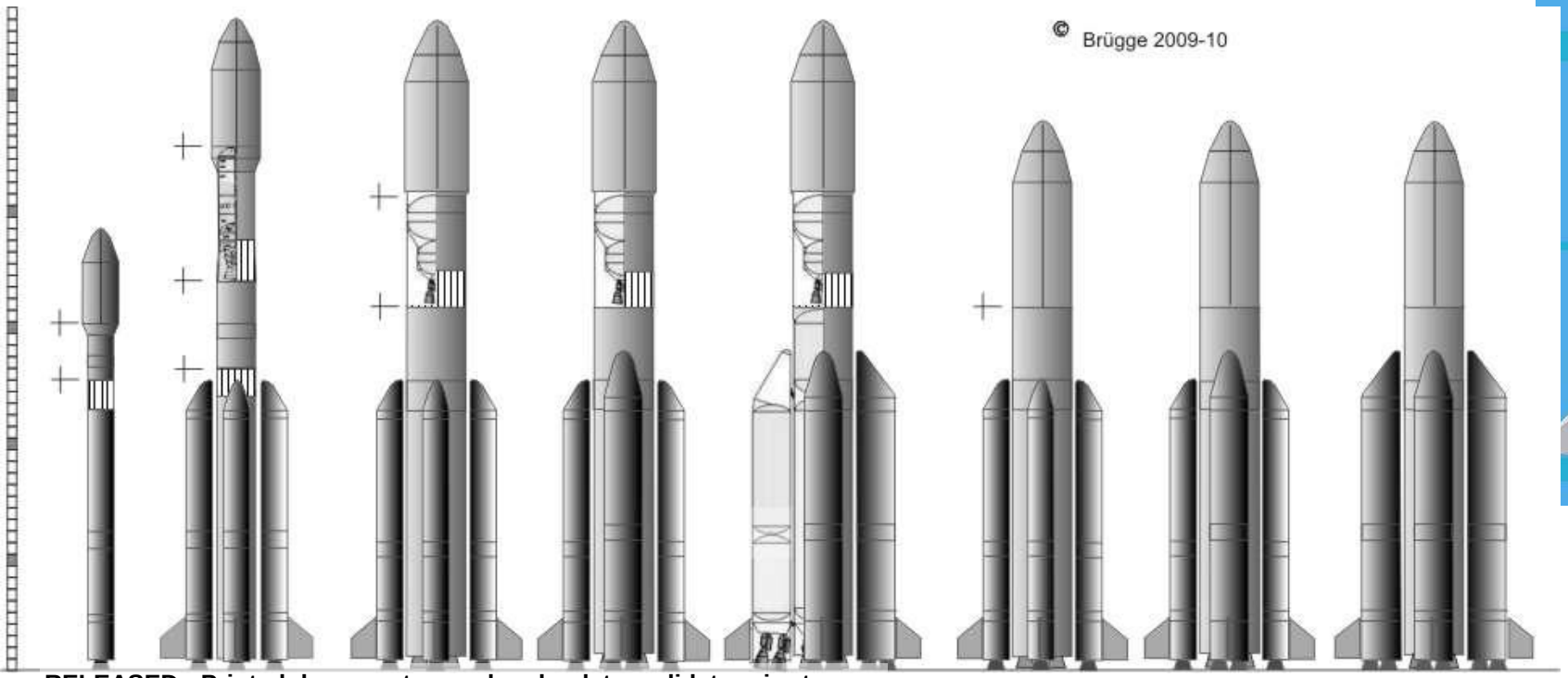
Angara Series

What's Next - China

YF-77
(LOX/LH)

YF-100
(LOX/RP1)

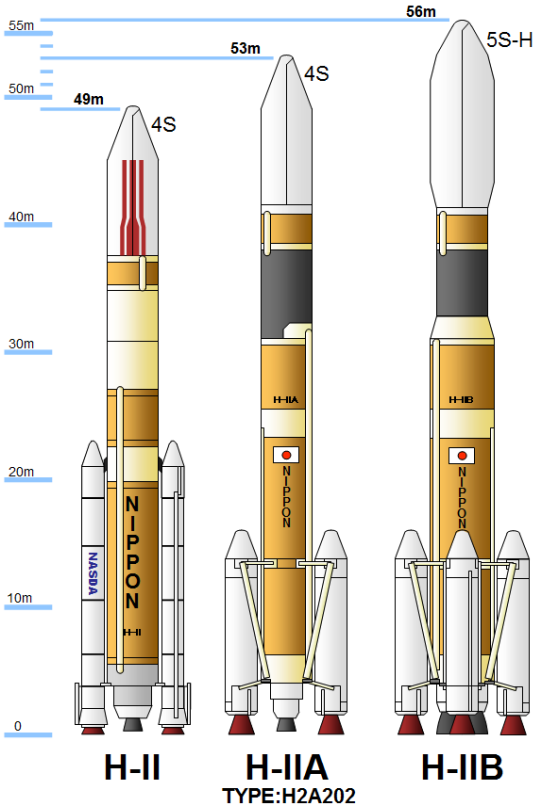


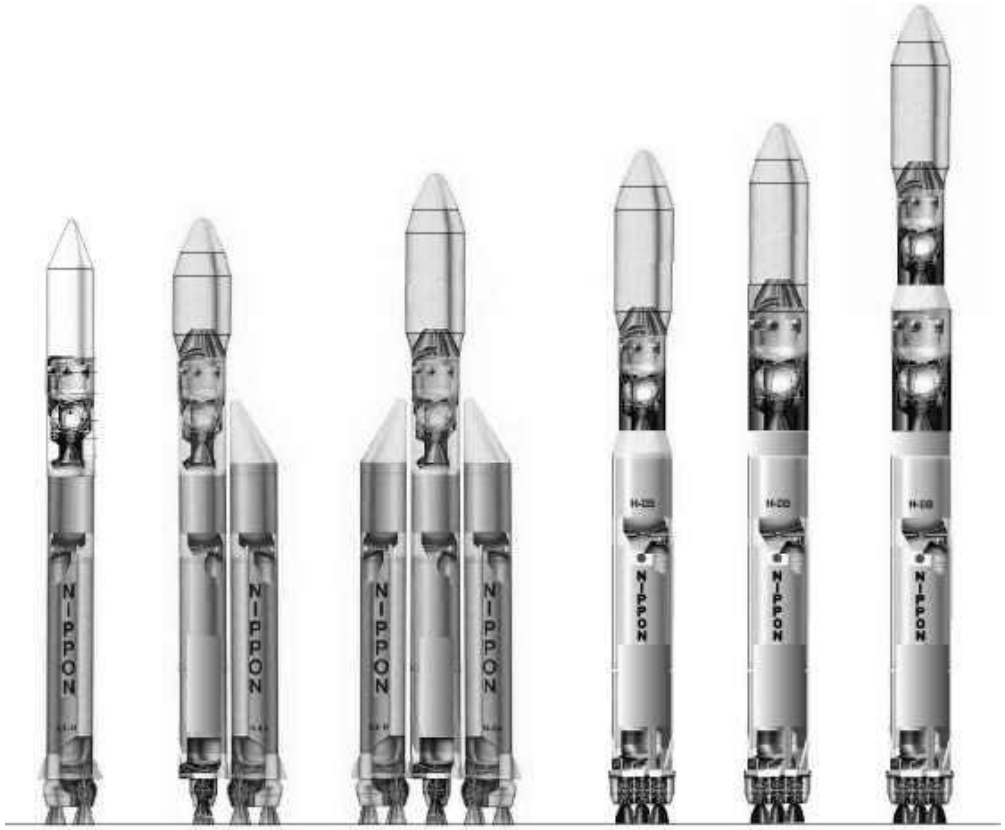


What's Next - ESA

Vega + Soyuz + Ariane = Fleet

What's Next - Japan





LE-X
(LOX/LH)

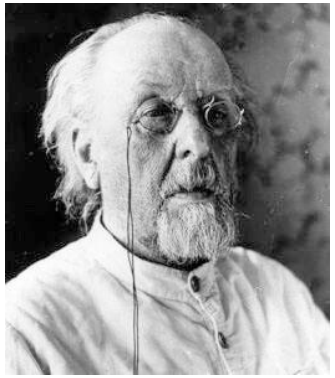
H-II Series

H-X Series

General Trends

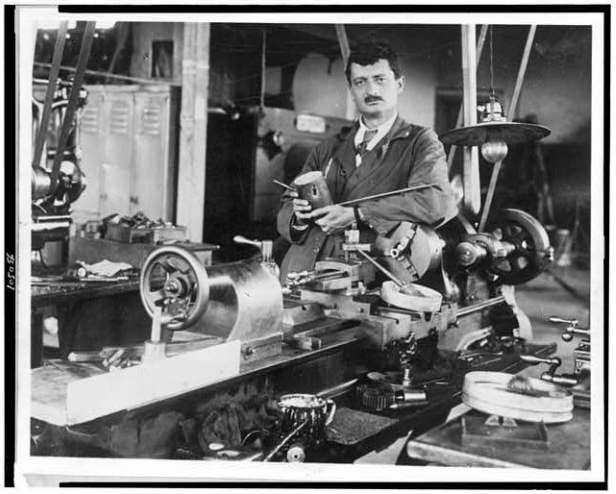
- Space launch vehicle begins with a basic propulsion stage, and serves as a missile or small launch vehicle; many are traceable to the 1945 German A-4
- Increasing stage size, and increasingly energetic propulsion allows for heavier payloads and greater Earth to Orbit lift capability
- Liquid rocket 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



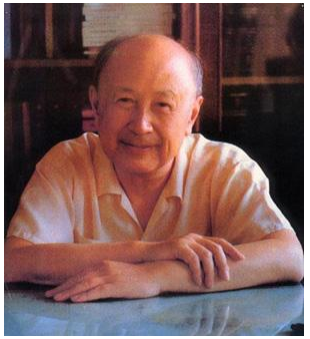
Goddard

Oberth

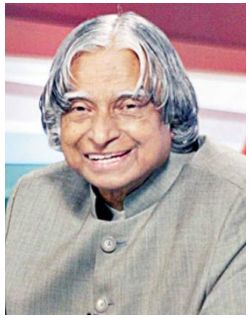


Korolyov

Von Braun



Tsien



Abdul Kalam

Yuri

… and many more!