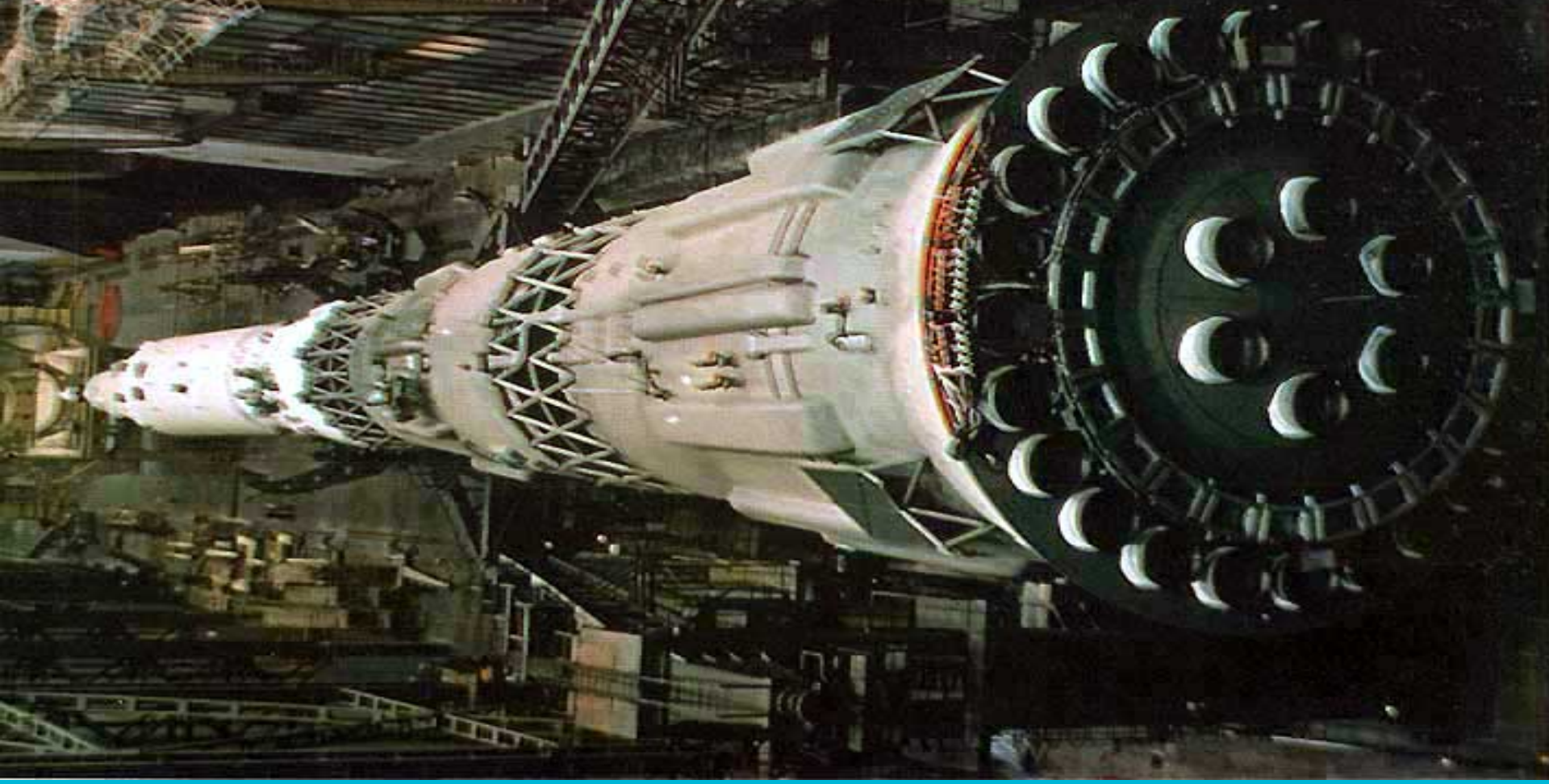


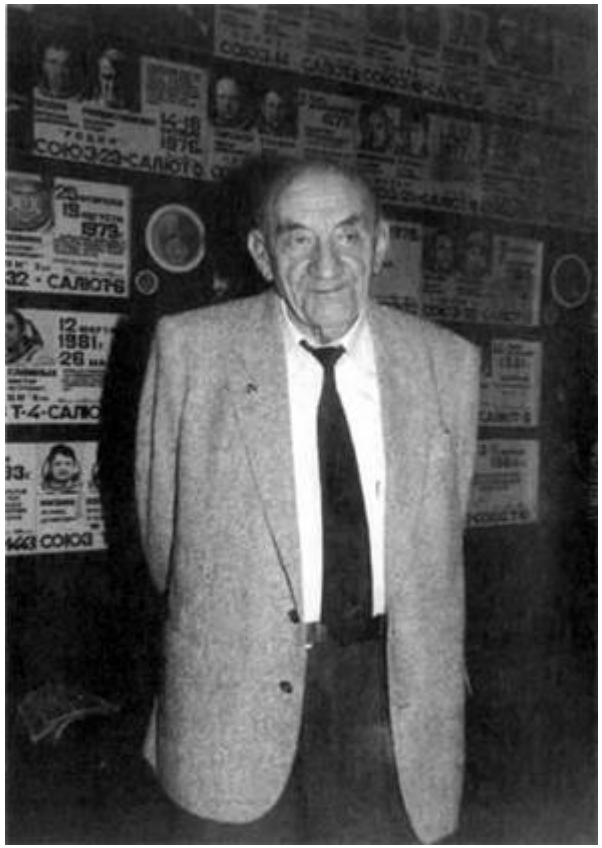
The Moon race from the other side of the Iron Curtain

Astronomy and Space Science
www.csiro.au

Max Voronkov | Senior Research Scientist

Co-learnium, Marsfield – 16 May 2019

“Rockets and People” by Boris Chertok



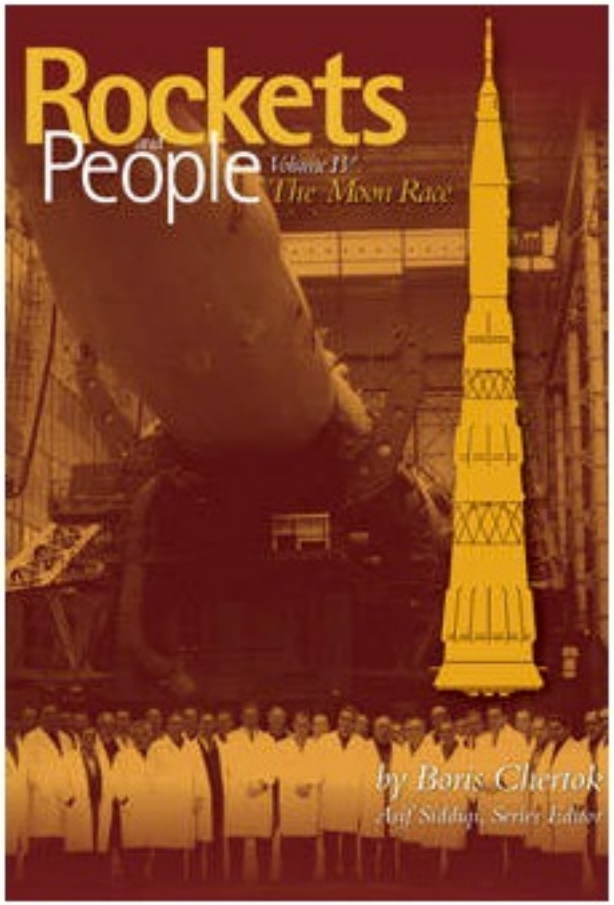
Борис Чертok
Boris Chertok
(1912-2011)

- Extensive memoirs:

Four books about the Soviet space program called

“Rockets and People”

- The 4th book is about the Moon Race
- English translation done by the NASA’s History Division



Rockets and People, Volume 4
Credits: NASA

PDF is available for free at the NASA website:

https://www.nasa.gov/connect/ebooks/rockets_people_vol4_detail.html

Let’s start with some names first

Сергей Королёв
Sergei Korolev
(1907(6) – 1966)

Other spellings of the name exist: e.g. Korolyov

Василий Мишин
Vasiliy Mishin
(1917 – 2001)

Валентин Глушко
Valentin Glushko
(1908 – 1989)

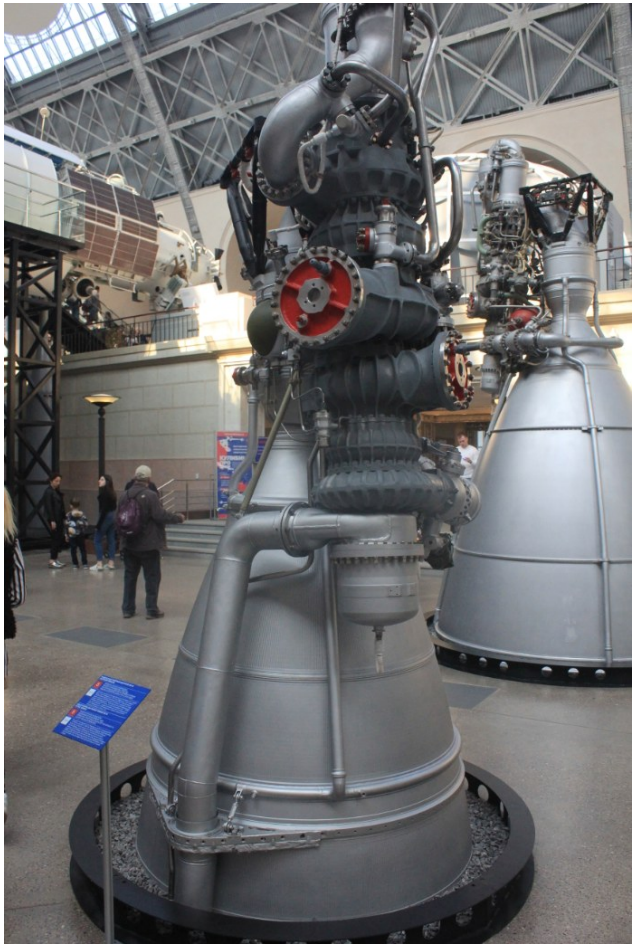
Image credit: Горизонты техники / wikipedia, Boris Chertok Rockets & People

Some problems of powerful rocket engines

- Gas dynamics, oscillations & resonances
- Ignition sequence
- Throttling
- Single start vs. ability to reuse

Fuel & oxidizer pair matters!
kerosene + liquid oxygen (LOX) is not the easiest pair

Problems rapidly increase with engine power



NK-15 engines in the Aviation and Space museum in Moscow

Image credit: https://historicspacecraft.com

Some Soviet Rockets

@LEO: ~5-7 tons ~25 tons ~95 tons ~100 tons

R-7, modern Soyuz
(In Russian: P-7)
Sputnik, Gagarin, Luna-9, etc

UR-500K
(in Russian: УР-500К)
modern Proton
e.g., Zond/L1, E-8

N1

Energia

I won’t talk about Ye-8 (E-8 in Russian), etc

N1-L3 (Н1-Л3 in Russian) Launcher + lunar spacecraft

- Paper project in late 1950s
  - Just N1, no specific payload
  - Mass at launch 2200 tons
  - Spherical tanks
  - 75 tons at low Earth orbit (LEO)
  - Intermediate step - N11 rocket
  - Kuznetsov NK-15 engines (blocks A and B), NK-9 (block V)
  - Differential thrust control in 2 axes
- 13th May 1961 political decision to build N1 by 1965
  - Not a very self-consistent plan
  - Defence (kind of CDR) of the N1 project 16th May 1962.
  - Go ahead 24th September 1962

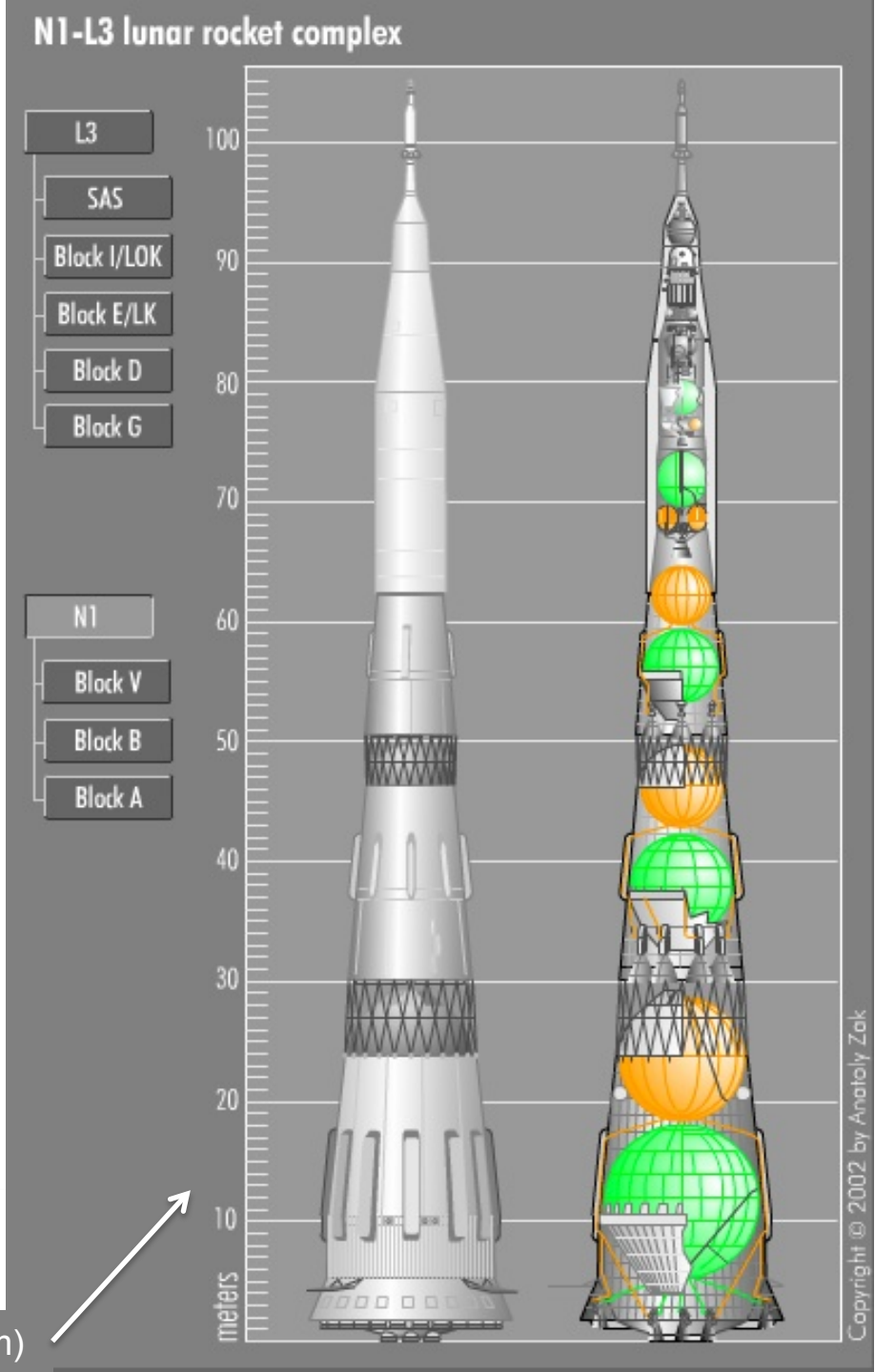


Image credit: Anatoly Zak (http://www.russianspaceweb.com)

Till the end of 1963 – plan for 3 N1 launches

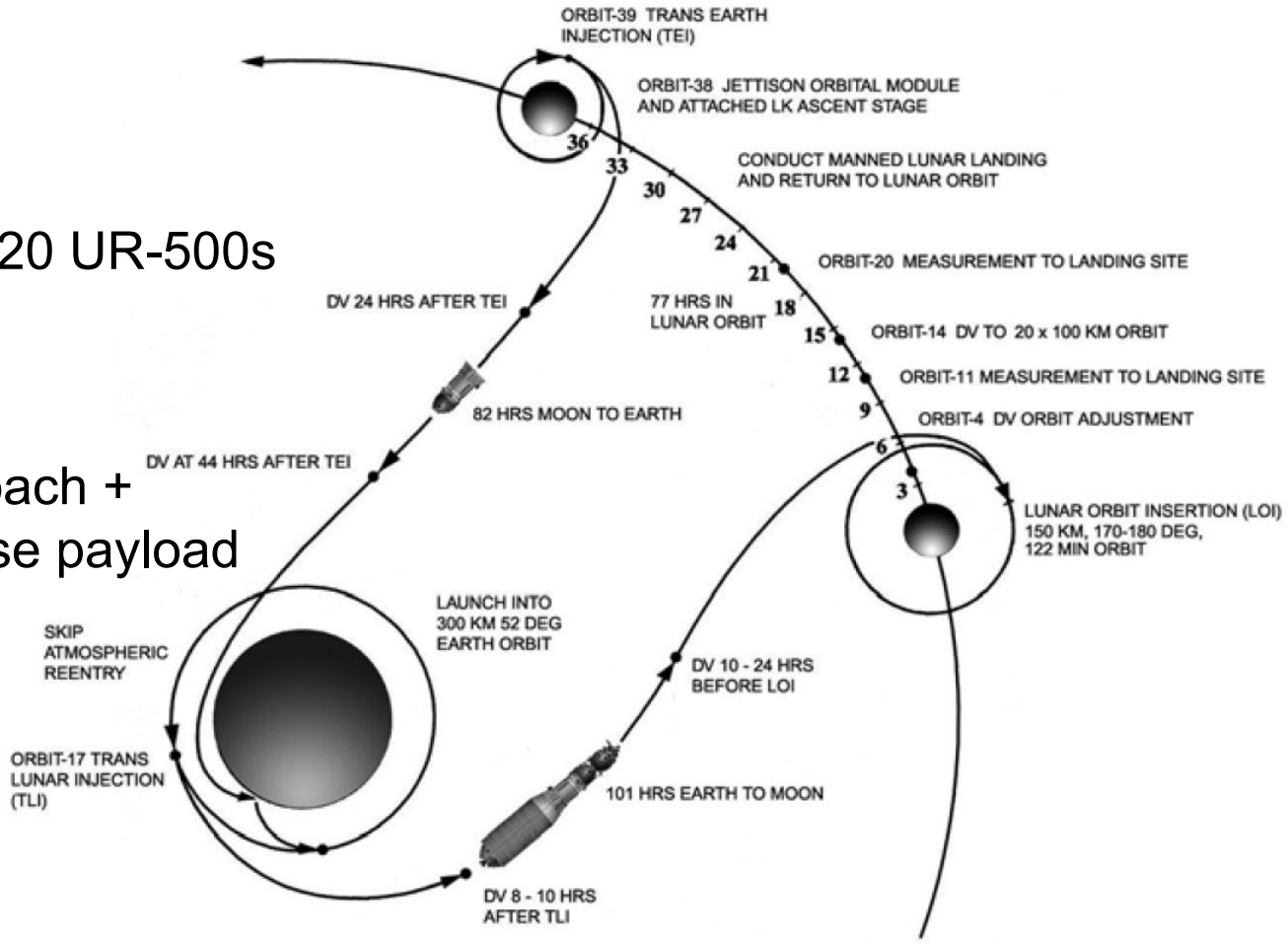
- Design of the lunar spacecraft itself seriously started only in 1963
- A 3-launch initial approach (actually 4, people would be launched with R-7) would give a good reserve in weights:
  - send 21 tons spacecraft to the Moon and return 5 tons back to Earth

~200 tons at LEO:

3 early N1s = 20 UR-500s

Single launch approach + measures to increase payload

Weight crisis



David R. Woods

N1-L3 (H1-Л3 in Russian) in August 1964

- 75 -> 93 tons @ LEO
  - Add 6 engines in the inner ring
  - 24 outer engines as they were
  - 8 at the second stage, 4 at the third
  - 680 tons of kerosene, 1780 tons of LOX (take off weight 2750 tons)
  - 2 cosmonauts, 1 gets to the Moon
  - Due date shifted only to 1966!
- More or less self-consistent design by December 1965
  - 60V 1000 Hz 3 phase AC power
  - KORD – monitor and shutdown engines before they explode
- Start testing before 1969 is unlikely, mission itself 1972?

Image credit: Boris Chertok Rockets & People

First launch – 21 February 1969

- First seconds of flight – two engines (out of 30) shut down
- 69th second of the flight – flame out on all engines
- Rocket crashed 52km from the launch site
- Investigation quickly revealed that the engines were shut down by KORD, but details not clear till March

- Engine #6 (and then #24) – false alarm due to interference
- 6th second – burst pipe of oxygen pressure sensor
- 25th second – burst pipe of the fuel pressure sensor
- 55th second – mixture ignited
- 68th second – fire broke wire isolation, 1000 Hz got to KORD control signals -> shut down

Image credit: Boris Chertok Rockets & People

Second launch – 3 June 1969

- About 0.25s before lift off, engine #8 exploded
- Remaining engines worked for a bit and the rocket took off to about 200 m
- In 12s all but engine #18 were off, the rocket started to twist
- At 15th emergency ejection triggered
- At 23rd second the rocket crashed at the launch pad destroying it

More than a year to rebuild the launch pad

Later on, engine shutdown was blocked in first 50s

Image credit:
Boris Chertok / Rockets & People

Lunar spacecraft tests in 1970-1971

- Three flights to the low Earth orbit to test both lunar lander and lunar orbital spacecraft
- Insertion with other carrier rockets

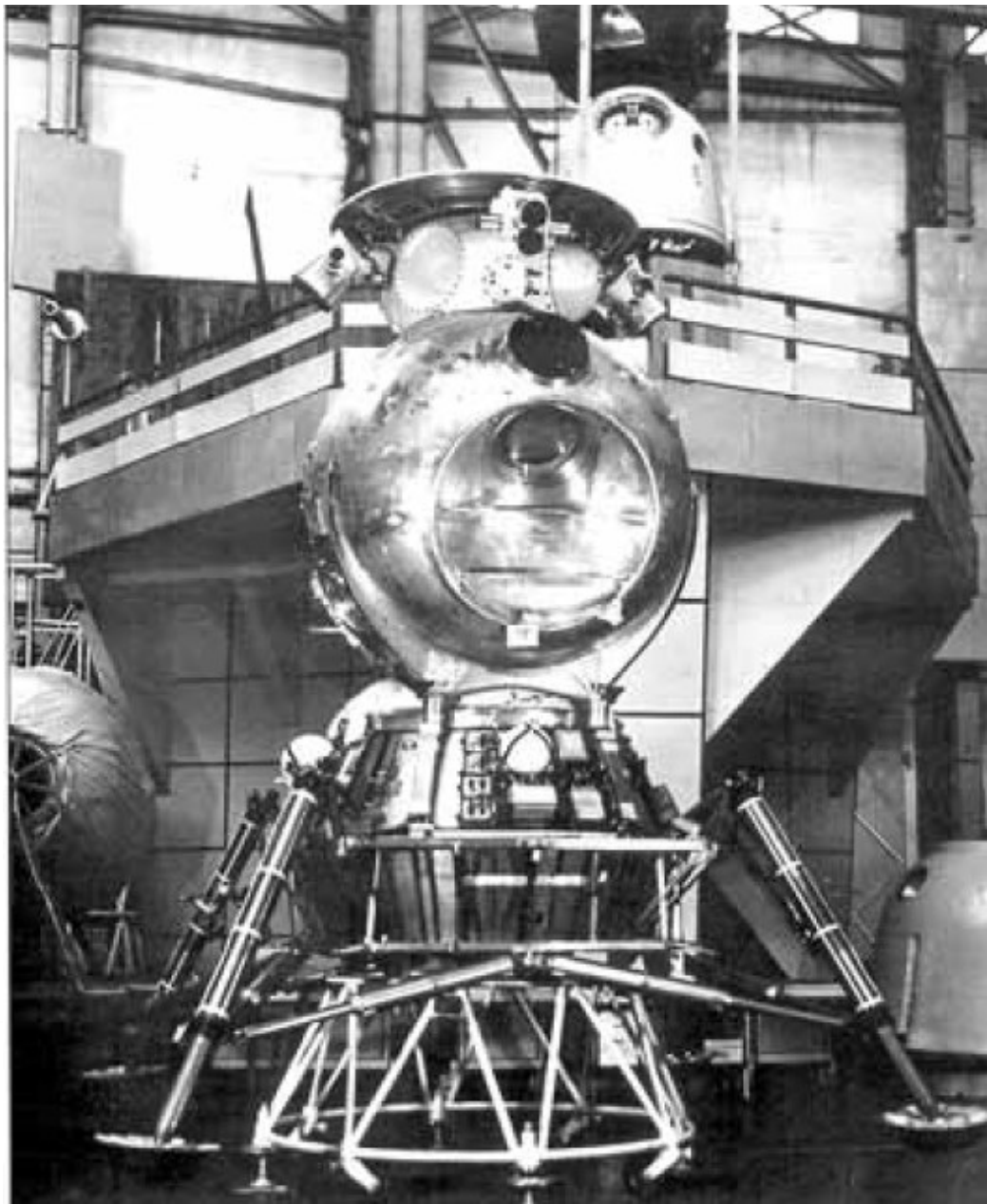


Image credit: Boris Chertok / Rockets & People

Third launch – 27 June 1971

- All engines started normally, but 5s into the flight roll angle started to increase
- At 14th second the roll angle exceeded 8 deg, but shutdown inhibited (for 50s)
- In 12s all but engine #18 were off, the rocket started to twist
- At 50th s the rocket had spun ~60 deg, all engines shut down -> crashed 20km away

It took a while to find the cause

Unexpected gas dynamics issue which was not in the model – not enough roll control

Image credit:
Boris Chertok / Rockets & People

The last (4th) launch – 23 November 1972

- Essentially a new rocket, but decision made not to wait for the new engines (still about year – 1.5 years) and install them from the next rocket
- New fire suppression system, new telemetry system, 4 more control engines
- Two on-board computers + standard upper stages
  - Wonders of s/w development and commissioning

- 95s central engines shut down as expected
- 100s flight normal
- 110s loss of information
- Separation was expected to take place at 113s

- Engine #4 explosion at 106.9s

Image credit:
Boris Chertok / Rockets & People

The end of N1-L3

- 21 May 1974 – reorganisation, Glushko appointed as the Chief
  - The first order was to cancel N1 program. Looked like it was pushed through.
  - Lots of impact on the industry. Hints that it was not decided yet higher up
- Formal government decision to terminate the N1-L3 program didn't appear until February 1976

- Didn't give up on the Moon, new rockets suggested
  - Even super-rocket capable of inserting 250 tons
- Lunar base was still a plan, but strong push for an analogue of Space Shuttle
- Fear it would delay having a super-heavy launcher by another 6-7 years
  - It took almost 13

Image credit:
Boris Chertok / Rockets & People

Why did the project fail?

- Technical reasons
  - Engines not reaching acceptable levels of reliability for 10+ years
    - single use requirement complicated acceptance testing
  - No ground testing of the assembled first stage
  - Single-launch approach making rocket not suitable for the mission
    - Time lost for modifications (6 more engines to get 95 vs. 75 tons)
    - Weight crisis (aggravated by no H+LOX upper stages)
- Managerial issues
  - No single governing body, multiple competing companies instead
    - Many lines of development using different technology
  - Project under-resourced, costs under-estimated, unrealistic deadlines
  - Personalities & conflicts
- Politics
  - Not building N11 rocket – no early testbed
  - No strategic decision to focus on the N1-L3 project until late in the game
  - Competition with military programs
  - Change of political government mid-60s

Thank you

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