Exploration and Geology of the Earth's Moon

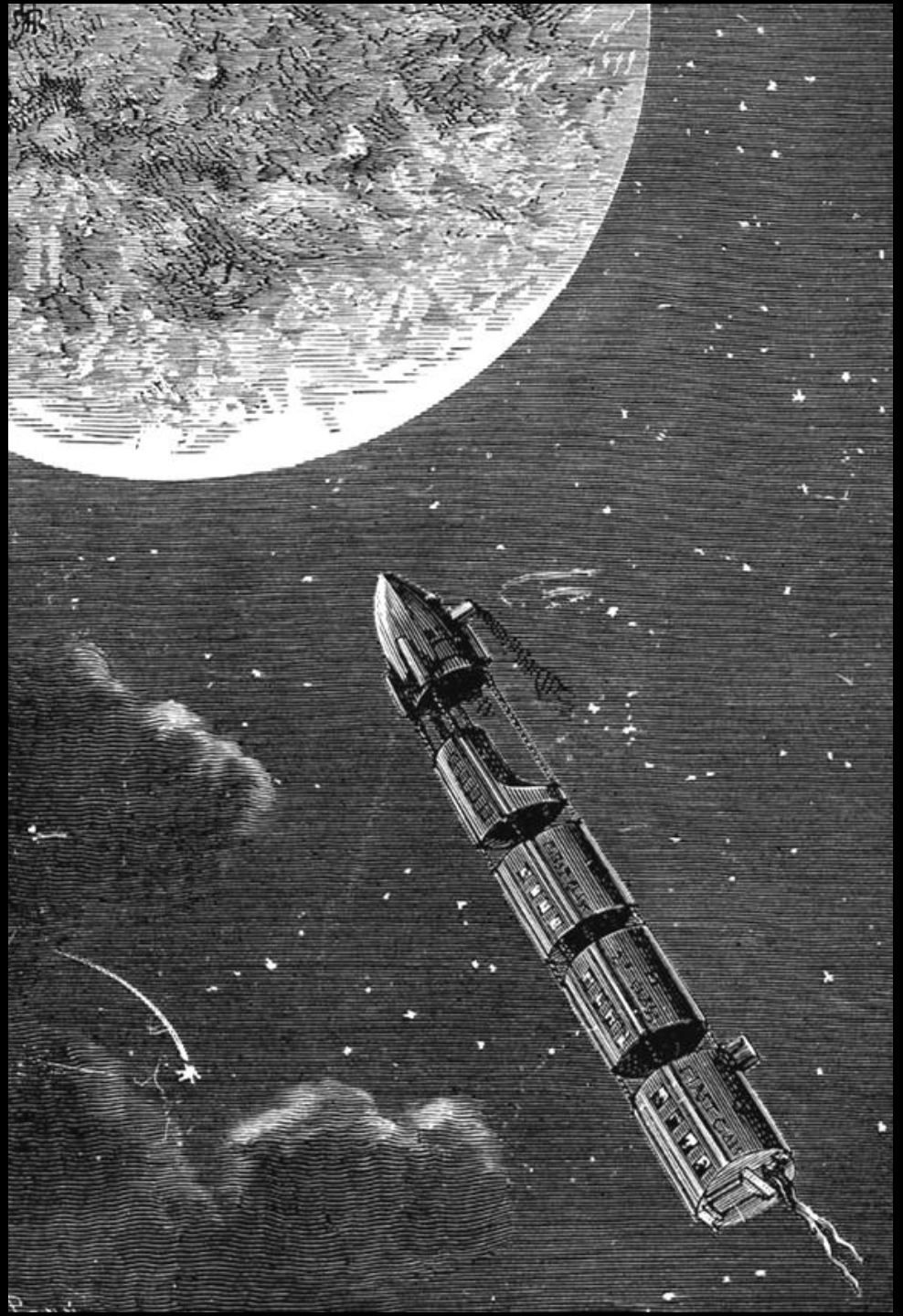
Firefly Blue Ghost – 02 Mar 25

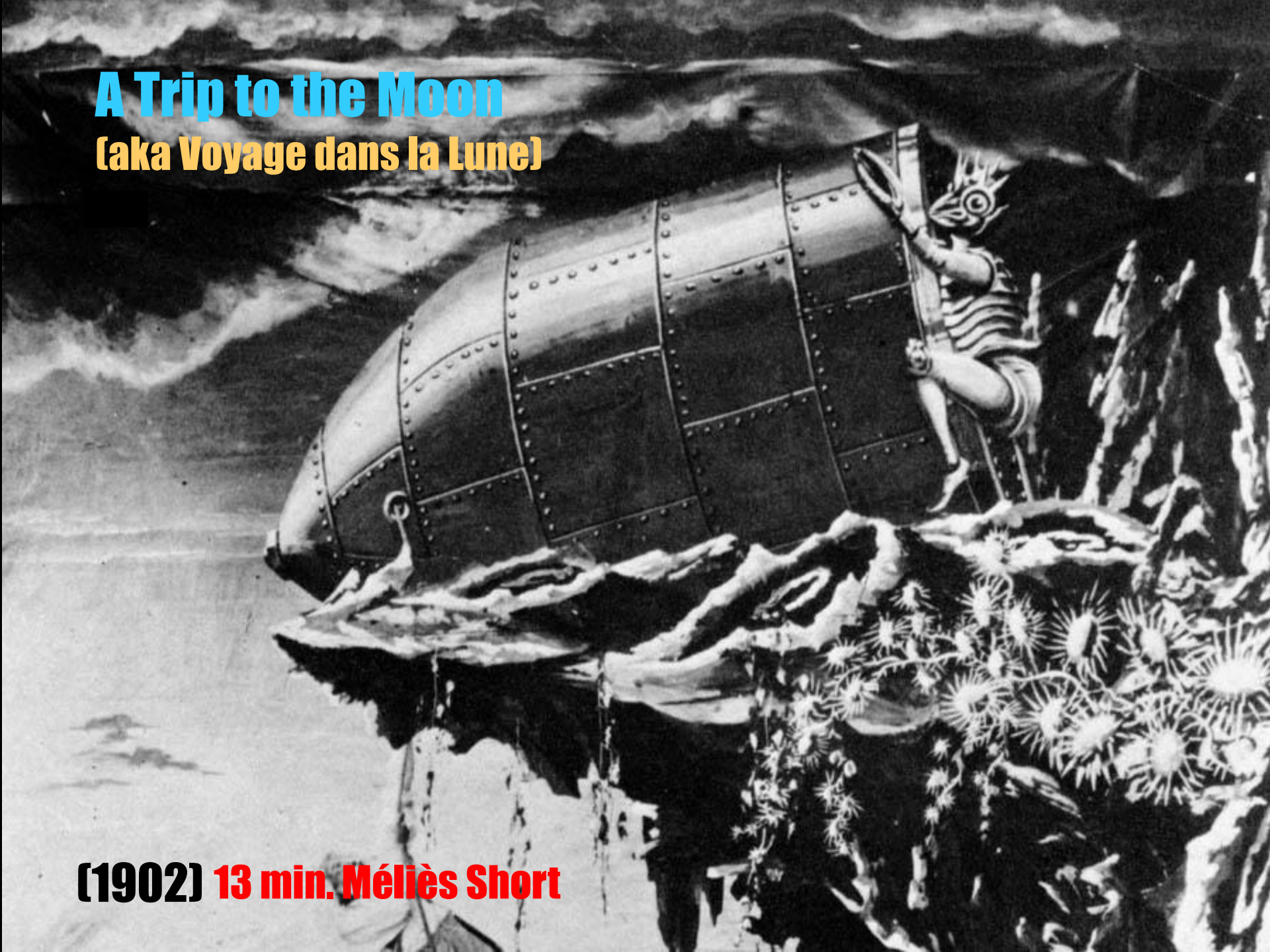
Franklin-Ogdensburg
Mineral Society (FOMS)
Saturday, 16 May 26

Charles Merguerian

Jules Verne
From the Earth to the Moon (1865)

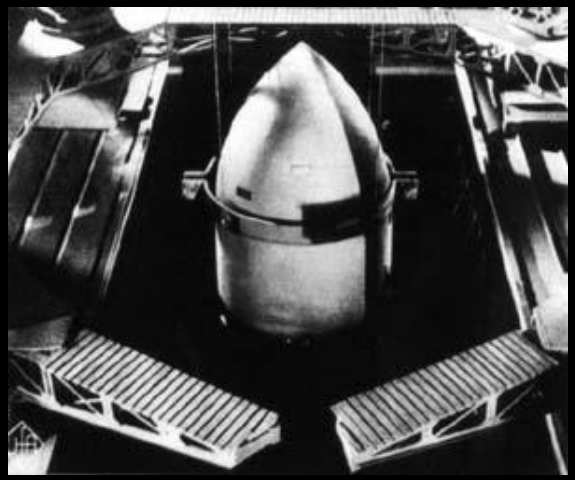
- Coal powered rocket to the Earth's Moon
- Foresaw military impetus for rocket program
- Predicted area near Cape Canaveral for U.S. launch site




A Trip to the Moon
(aka Voyage dans la Lune)
(1902) 13 min. Méliès Short

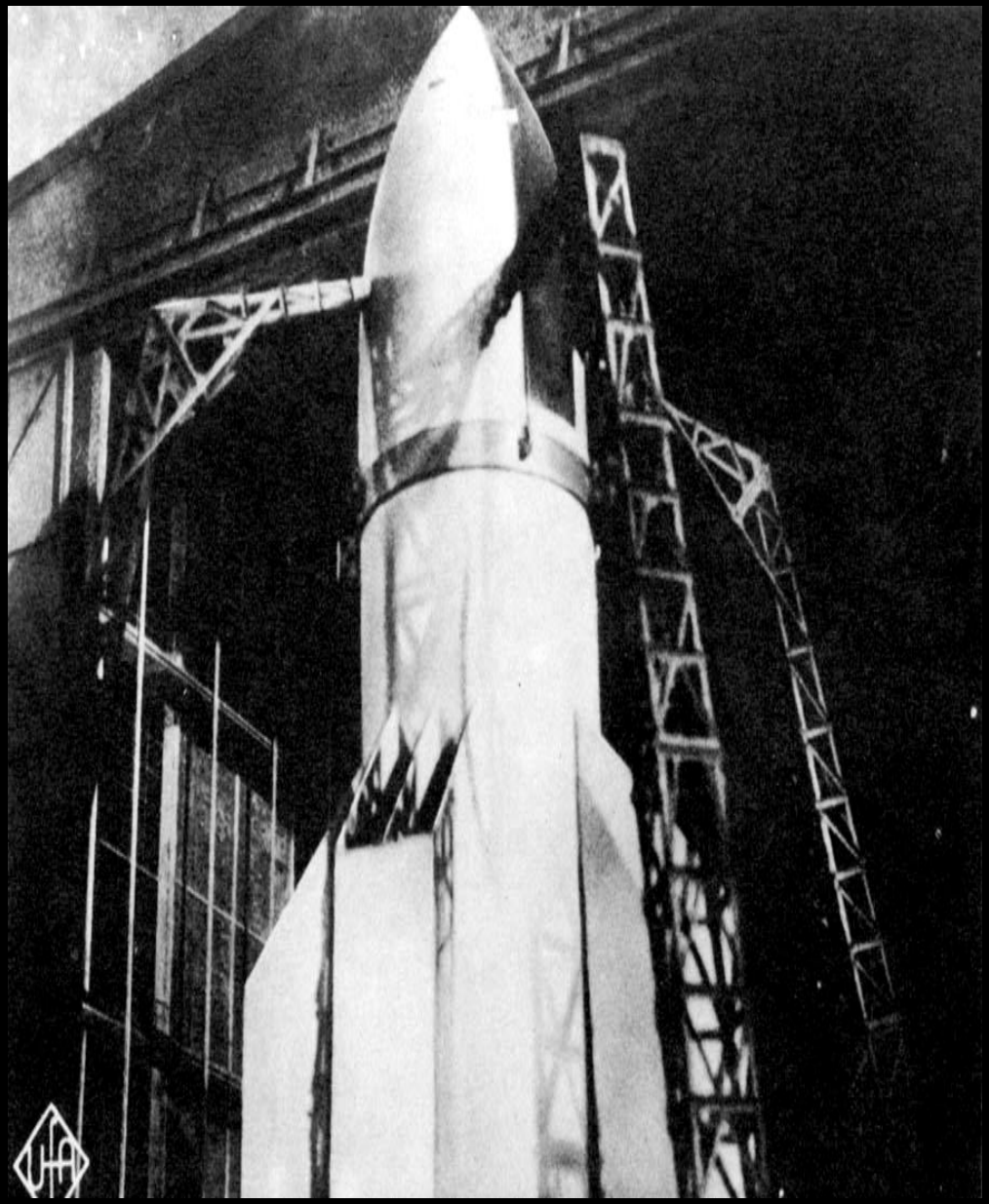
Woman in the Moon

(aka Frau im Mond; By Rocket to the Moon)



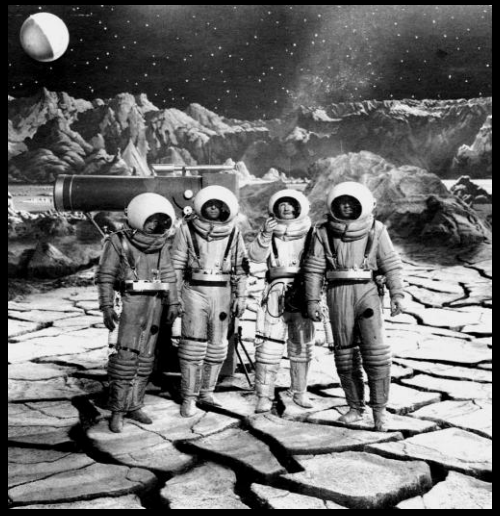
(1929)

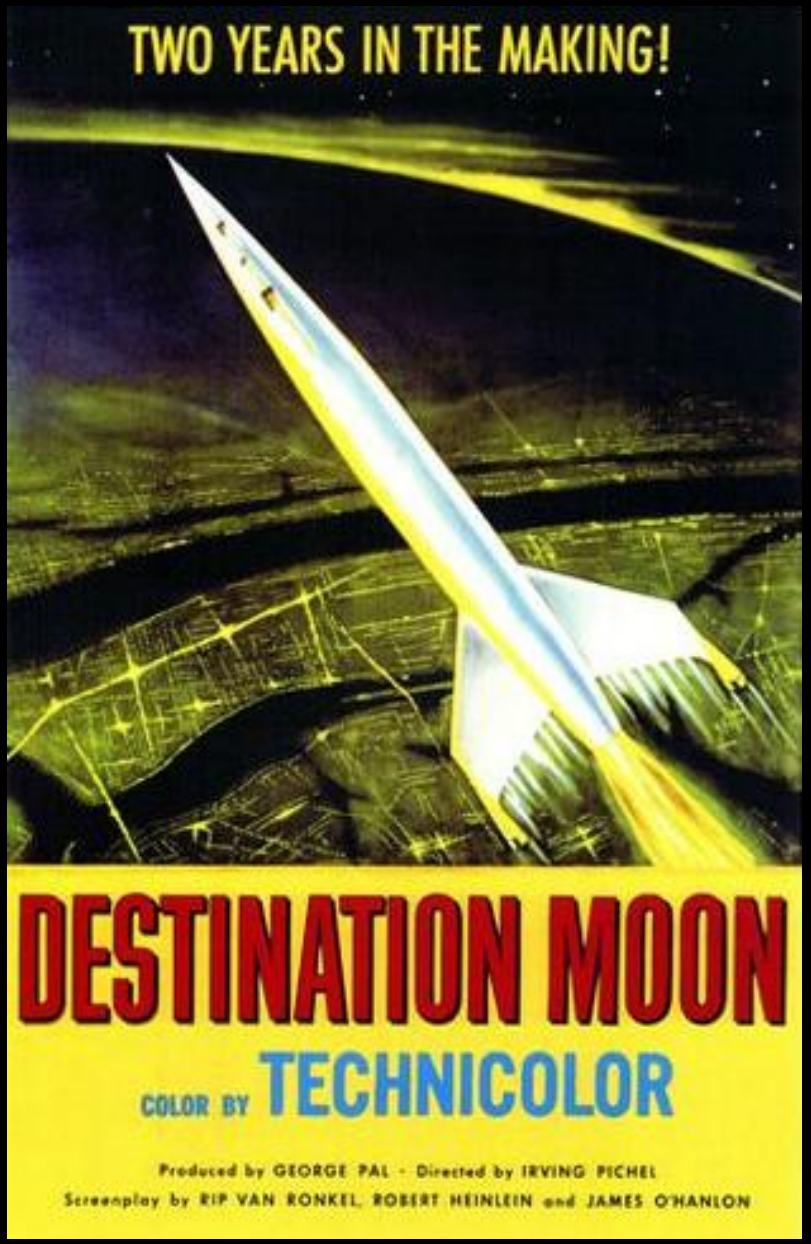
95 min.



(1929) - Rocket Built by Hermann Oberth for Film Opening

Destination Moon

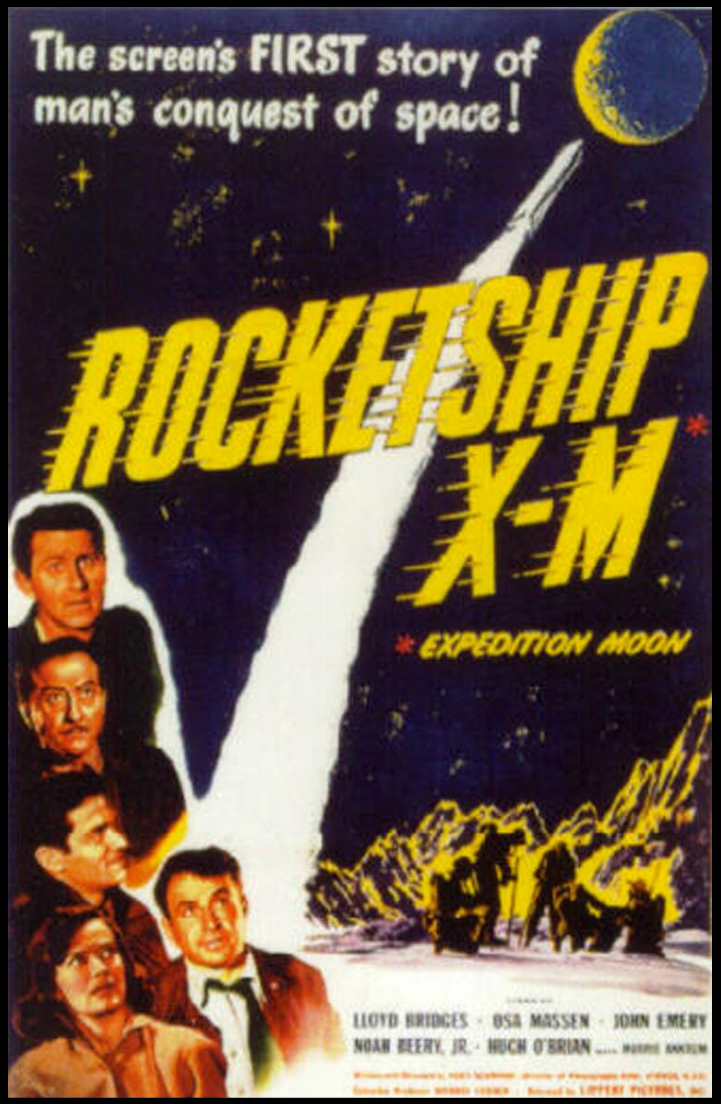




(1950)

92 min.

Rocketship X-M

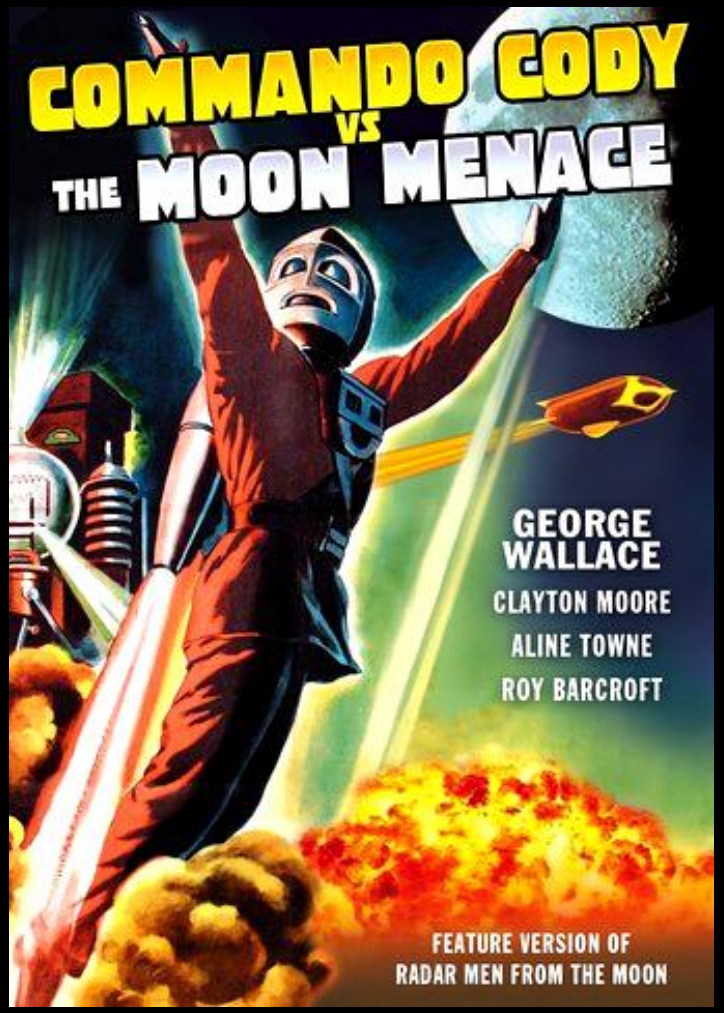


(1950)

77 min.

Radar Men from the Moon

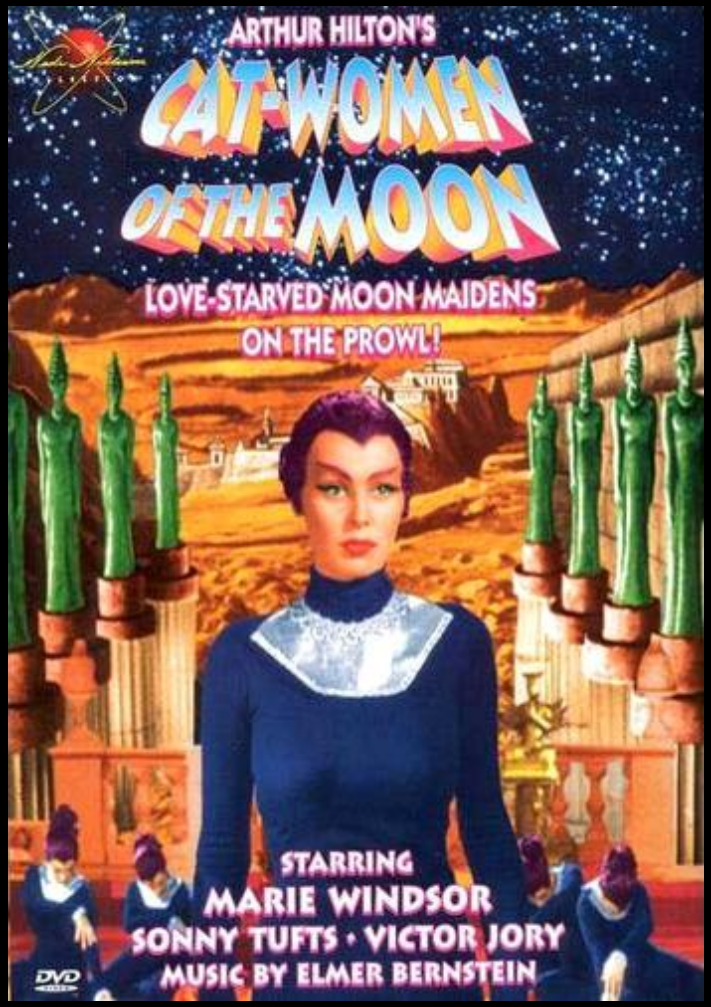
(aka Planet Men from Mars; Retik, the Moon Menace)

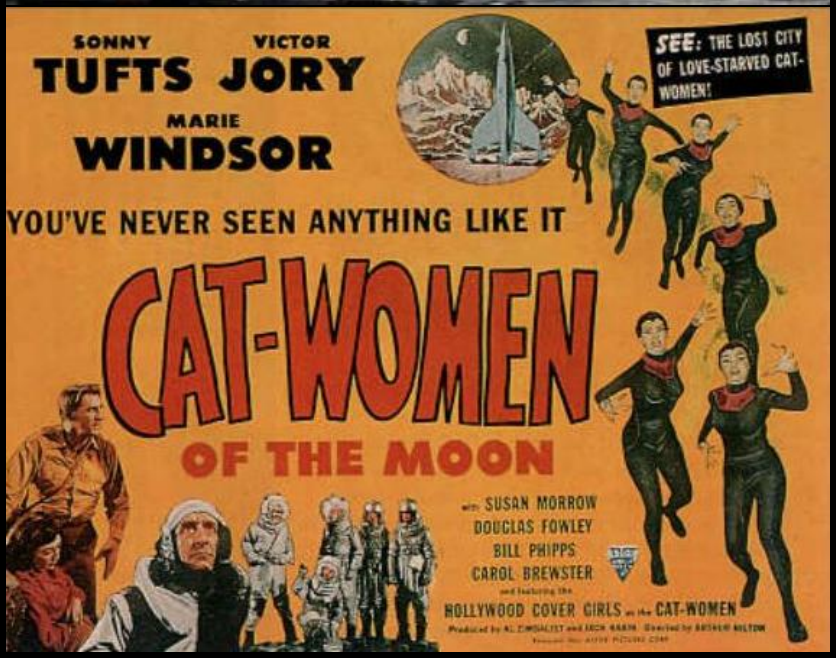


(1952)  2 hr. 47 min. 12-chapter Republic Pictures serial

Cat-Women of the Moon

(aka Rocket to the Moon)

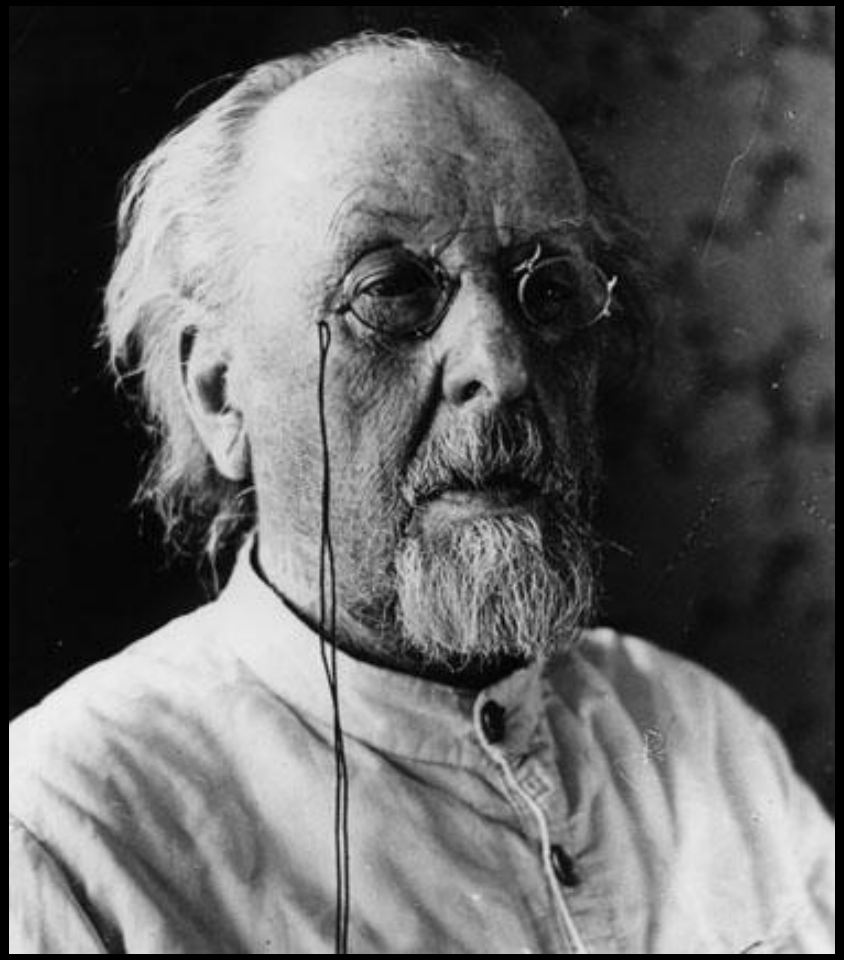




(1953)

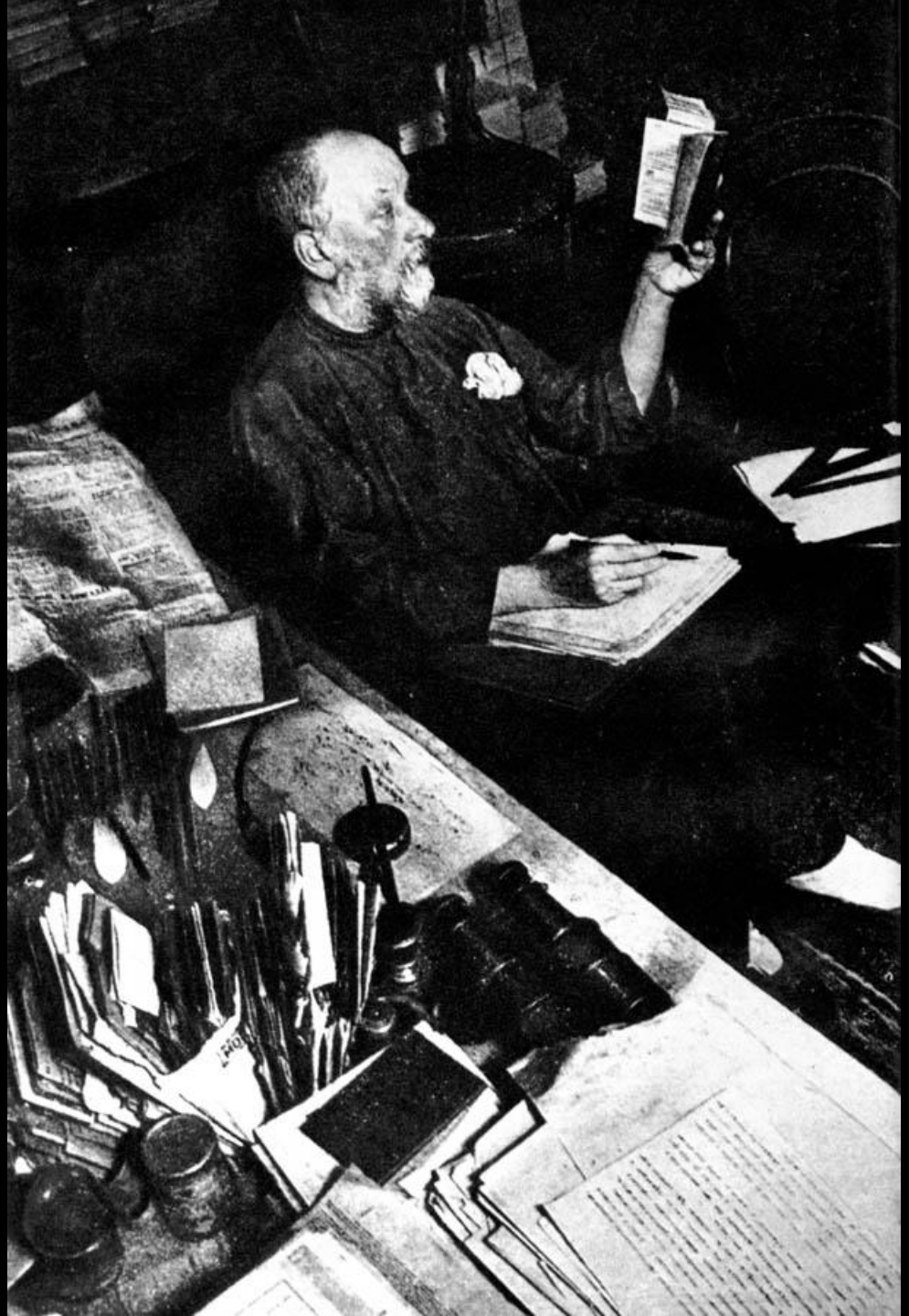
64 min.

Rocket Scientists



Tsiolkovsky

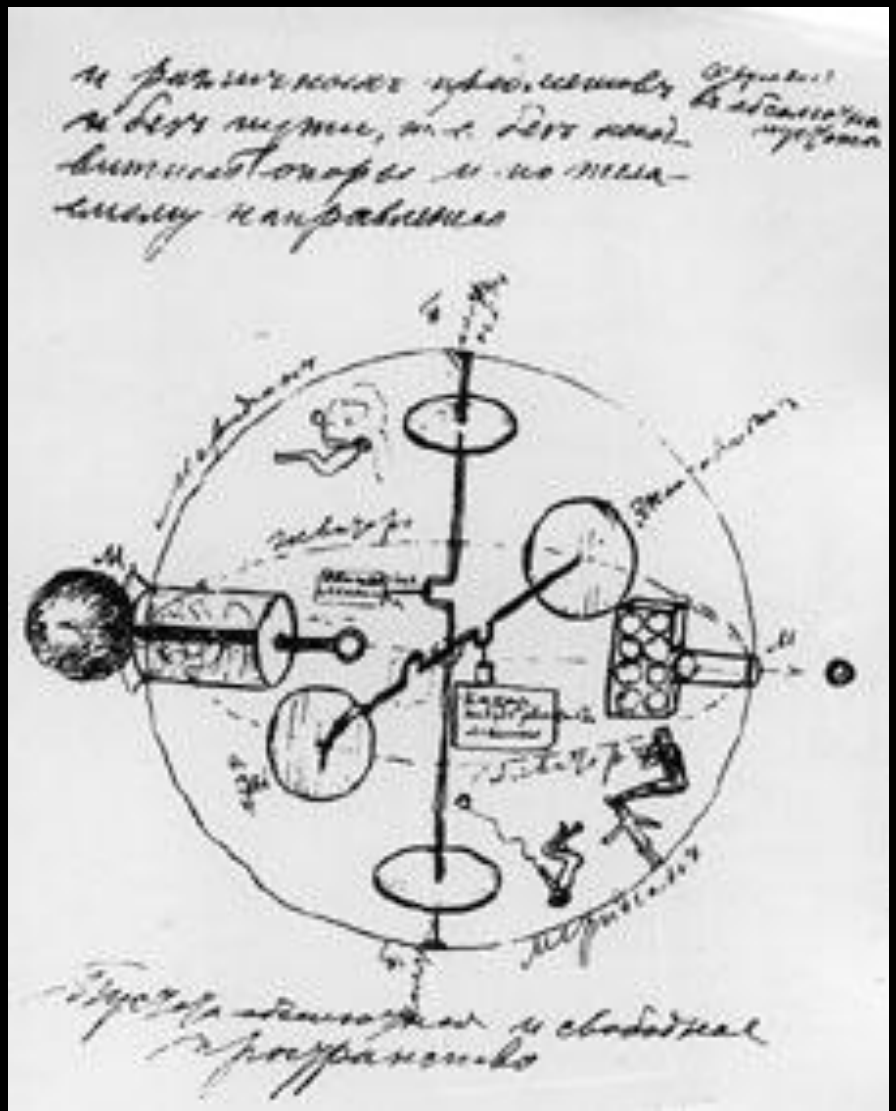
Goddard



Konstantin Eduardovitch Tsiolkovsky (1857-1935)

Russian School Teacher Pioneer in Soviet Rocketry

Wrote Free Space (1883) @ Age 26



Tsiolkovsky

28 Mar 1883 – Reaction principle in "Free Space"

1895 – Publishes "Dreams of the Earth and Sky"

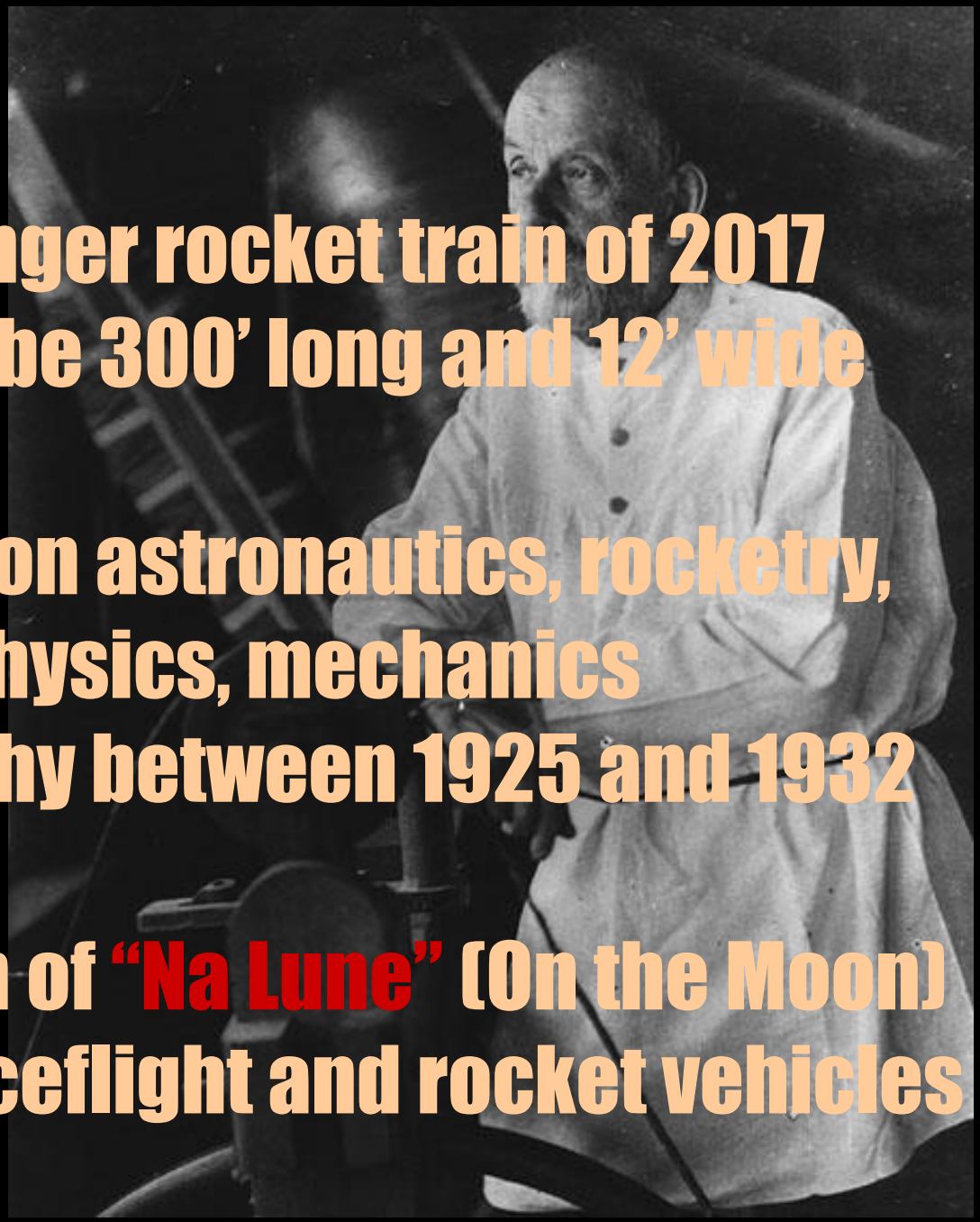
25 Aug 1898 – Reaction thrust motor

1903 – Publishes "Exploration of Space with Rocket Devices". Liquid oxygen and liquid hydrogen design and all basic equations for rocketry provided

Envisioned multi-stage rockets for deep space travel

Weightlessness

Tsiolkovsky



Envisioned passenger rocket train of 2017
The rocket would be 300' long and 12' wide

Wrote 60 articles on astronautics, rocketry,
astronomy, physics, mechanics
and philosophy between 1925 and 1932

1935 – Publication of "Na Lune" (On the Moon)
refers to spaceflight and rocket vehicles

Robert H. Goddard (1882-1945)

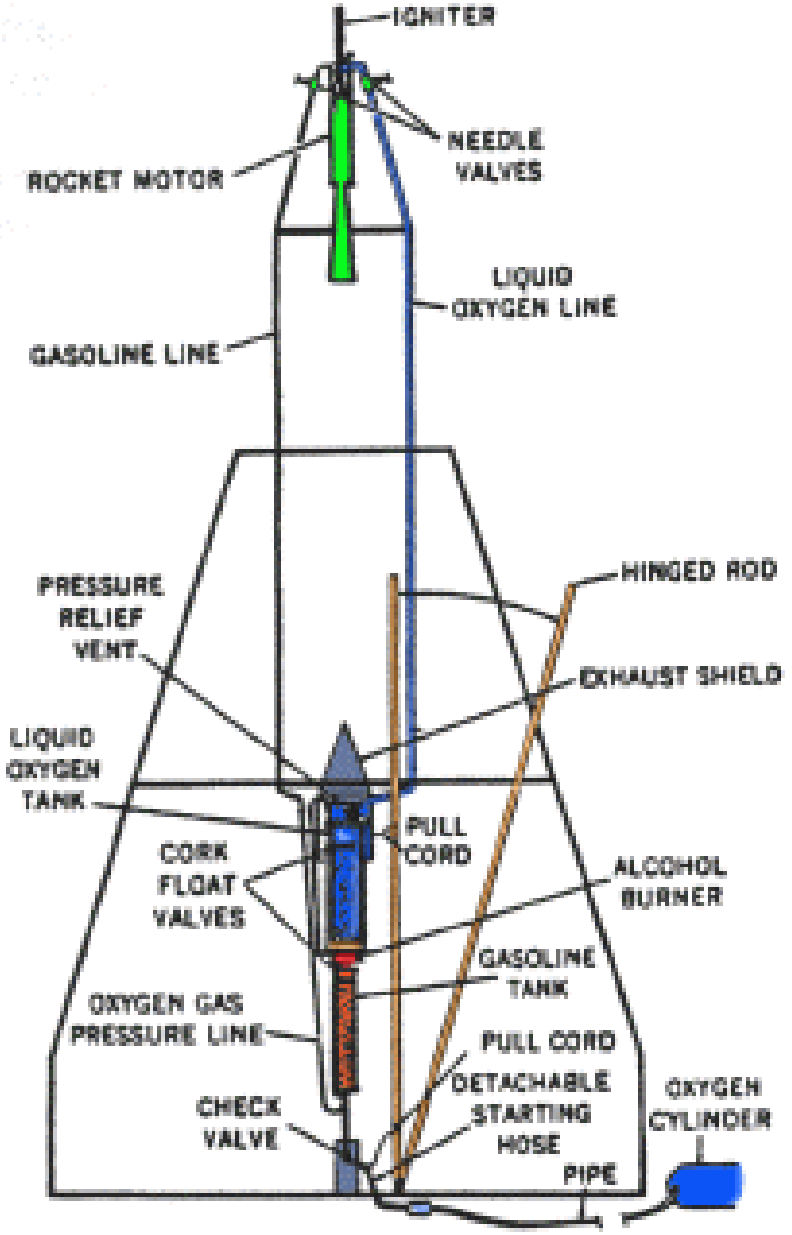
Father of American Rocketry

Independent Experimentalist

On the morning of 16 March 1926 barely a year after Wernher von Braun's rocket wagon fiasco, Goddard launched a liquid-powered rocket he had designed and built from a snow-covered field at his Aunt Effie Goddard's farm in Auburn, Massachusetts

The rocket flew only 46 meters -- about the same distance as the Wright Brothers' first manned flight -- it was the first flight of a liquid-fueled rocket in history

Goddard 16 March 1926 Rocket



Aunt Effie Goddard's farm in Auburn, Massachusetts

Goddard

Independently developed liquid fuel rockets

1909 – Discovers that liquid hydrogen and liquid oxygen served as efficient propulsion

1912 – Mathematic proof of the feasibility of using rockets for high altitude or lunar flight

1914 – Receives U.S. patent for multi-stage rocket and proves rocket would work in a vacuum

Goddard

1919 – Publishes paper on Moon travel but the subject of public ridicule. Prompts 16-year exile from public eye

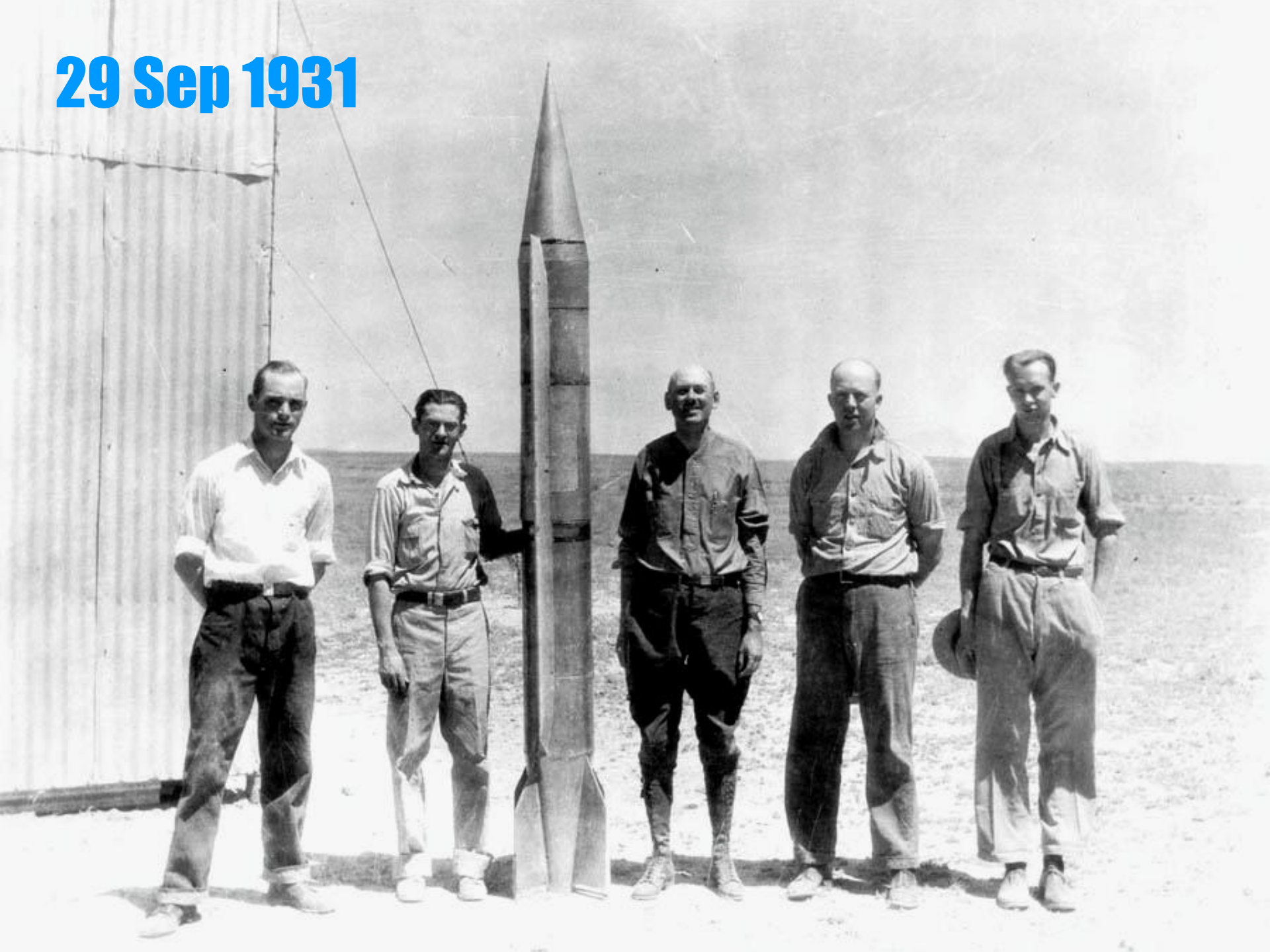
1926 – First successful liquid fuel rocket launch!!

1929 – First scientific payload on a rocket (Barometer and Camera)

1932 – Guidance systems and gyro control

1937 – Guided rocket launched with gimbaled motor and gyro mechanism

29 Sep 1931



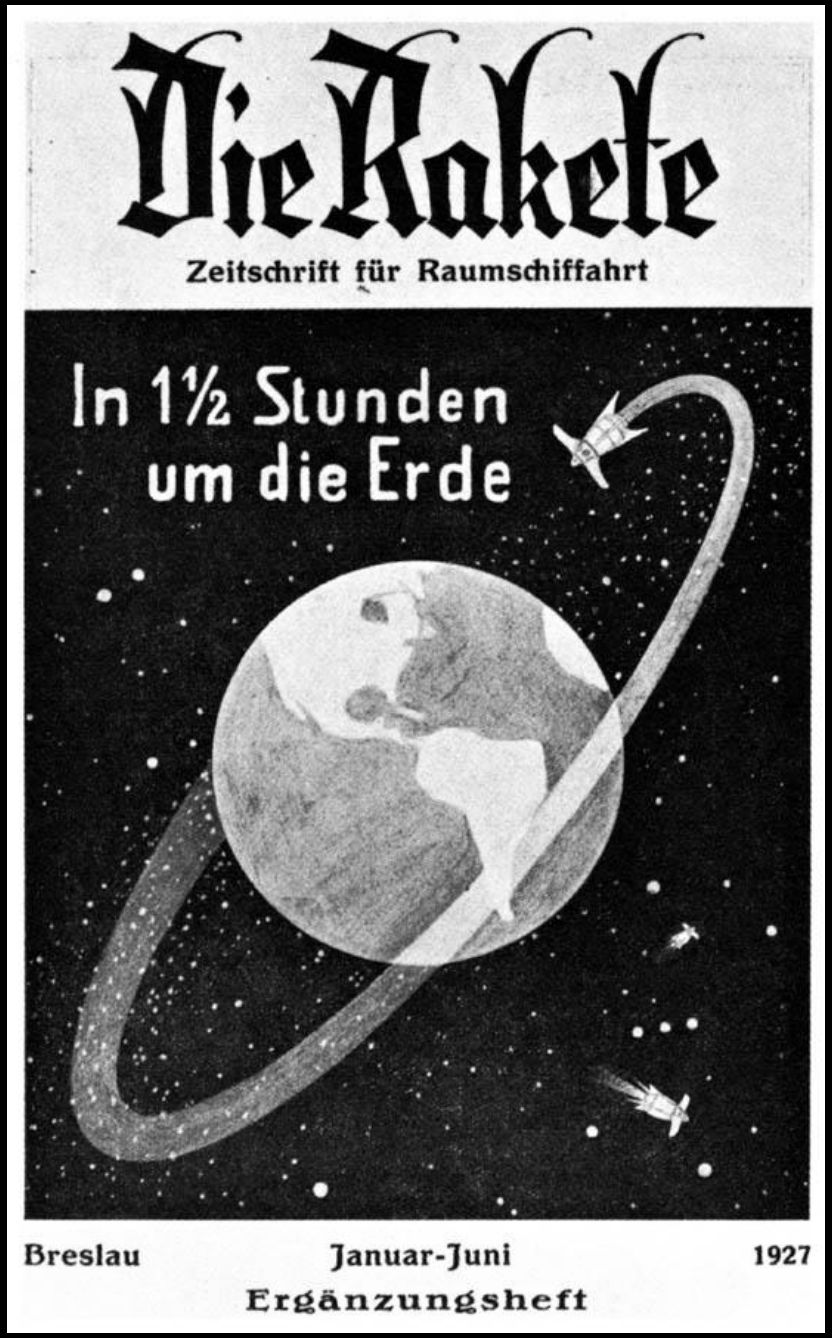
1935

Die Rakete

1927

Monthly Journal of German Society for Space Travel

Civilian Societies:
United States
Soviet Union
France
Britain



Max Valier

15 Mar 1928

Member of German VfR (Society for Space Travel)

Wrote: The Advance into Space (1924)

Rocket Car (Opel) Used Liquid Propellant

Soviet Union Rynin's Interplanetary Communications Vol. 3

Nine-Volume Encyclopedia (1928-1932)

Hermann Julius Oberth

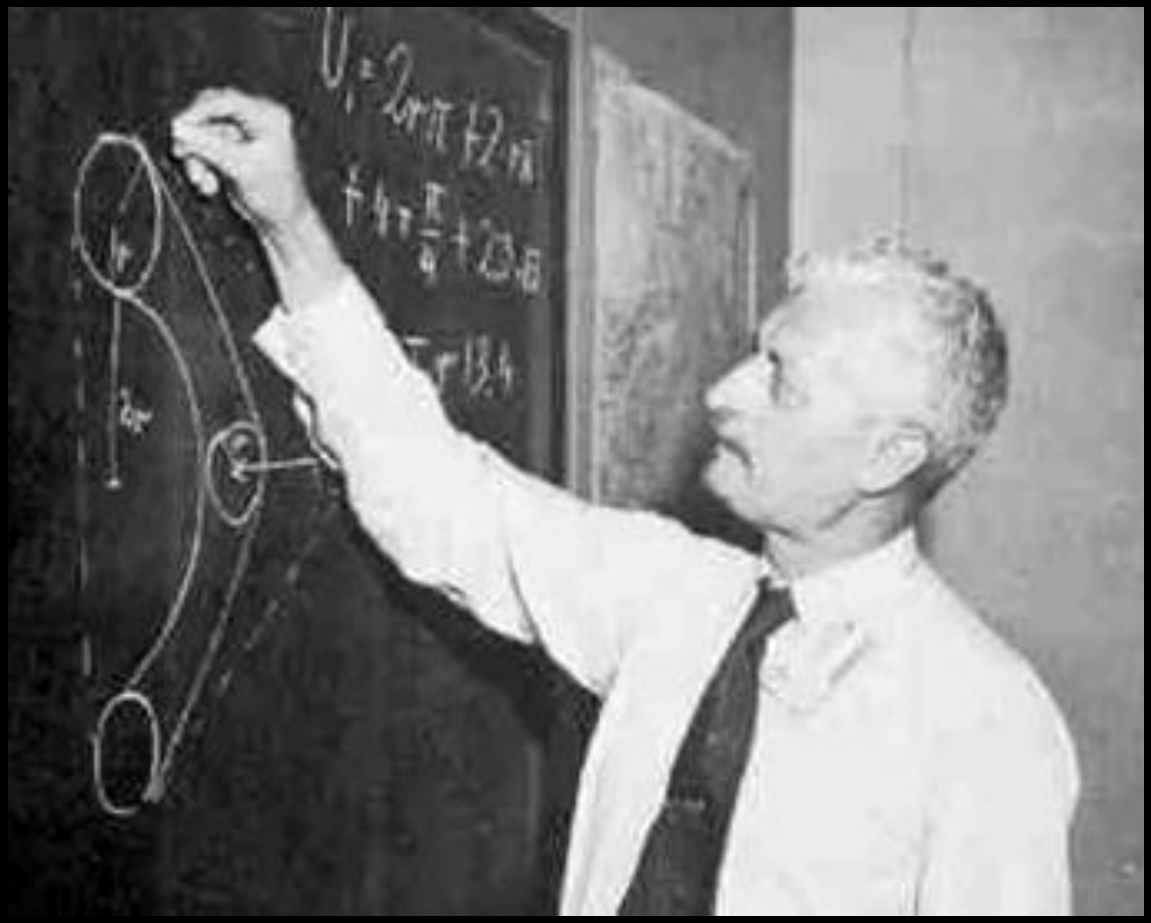
(1894-1989)

Born in Hermannstadt, Transylvania, Romania

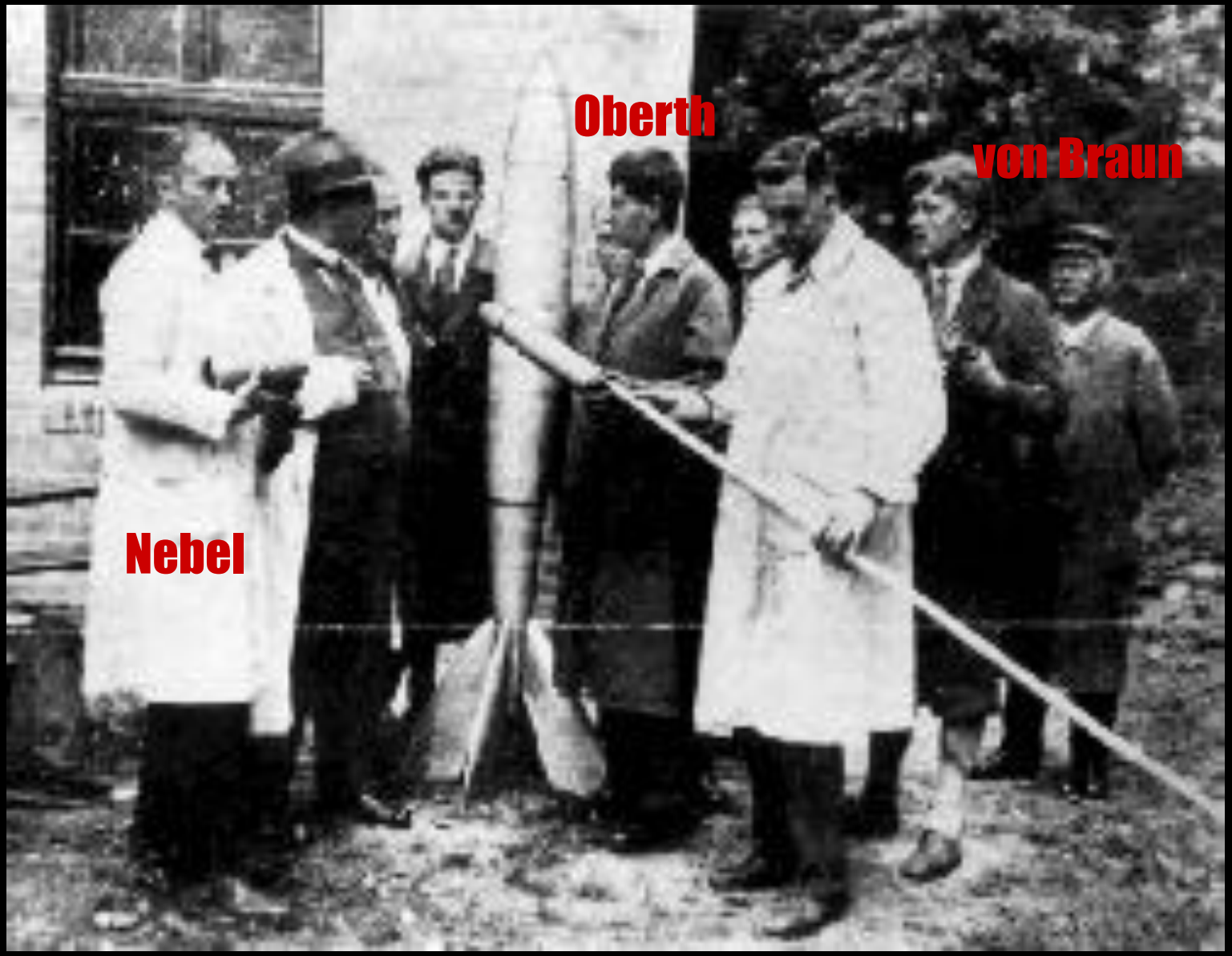
Read Jules Verne at Age 11 – Fascinated with Space Travel

Publishes Die Rakete zu den Planetenraumen (The Rocket into Planetary Space, 92 p.) in 1923
A longer version in 1929 (429 p.) gained acclaim

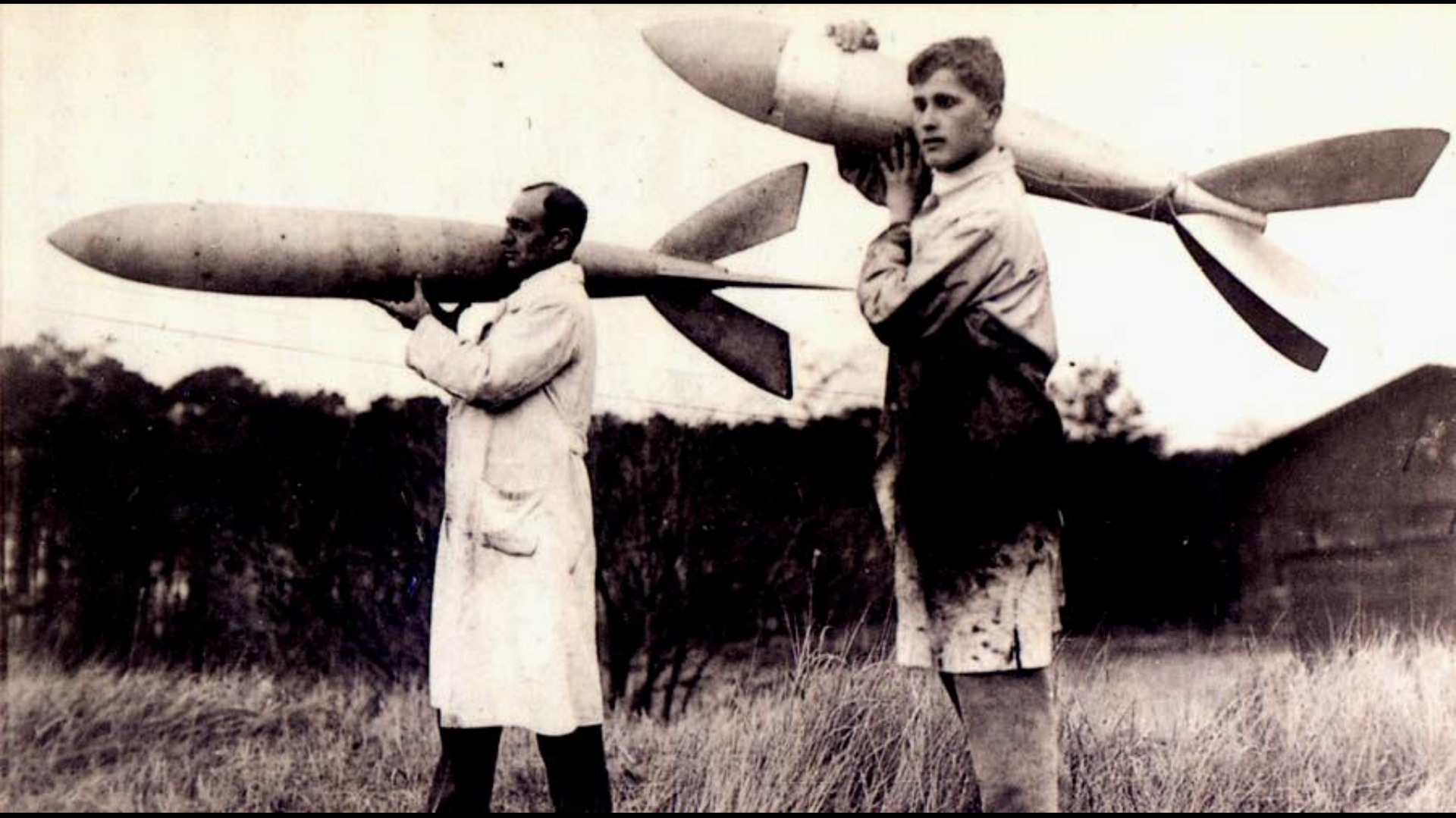
Worked with Dr. Wernher von Braun first in the 30s, then at Peenemunde during WWII, and in the U.S. in the 1950s and 1960s



Oberth Rocket



Rudolf Nebel and Wernher von Braun (age ~19)



Oberth's Repulsor Rockets at Raketenflugplatz (~1932)

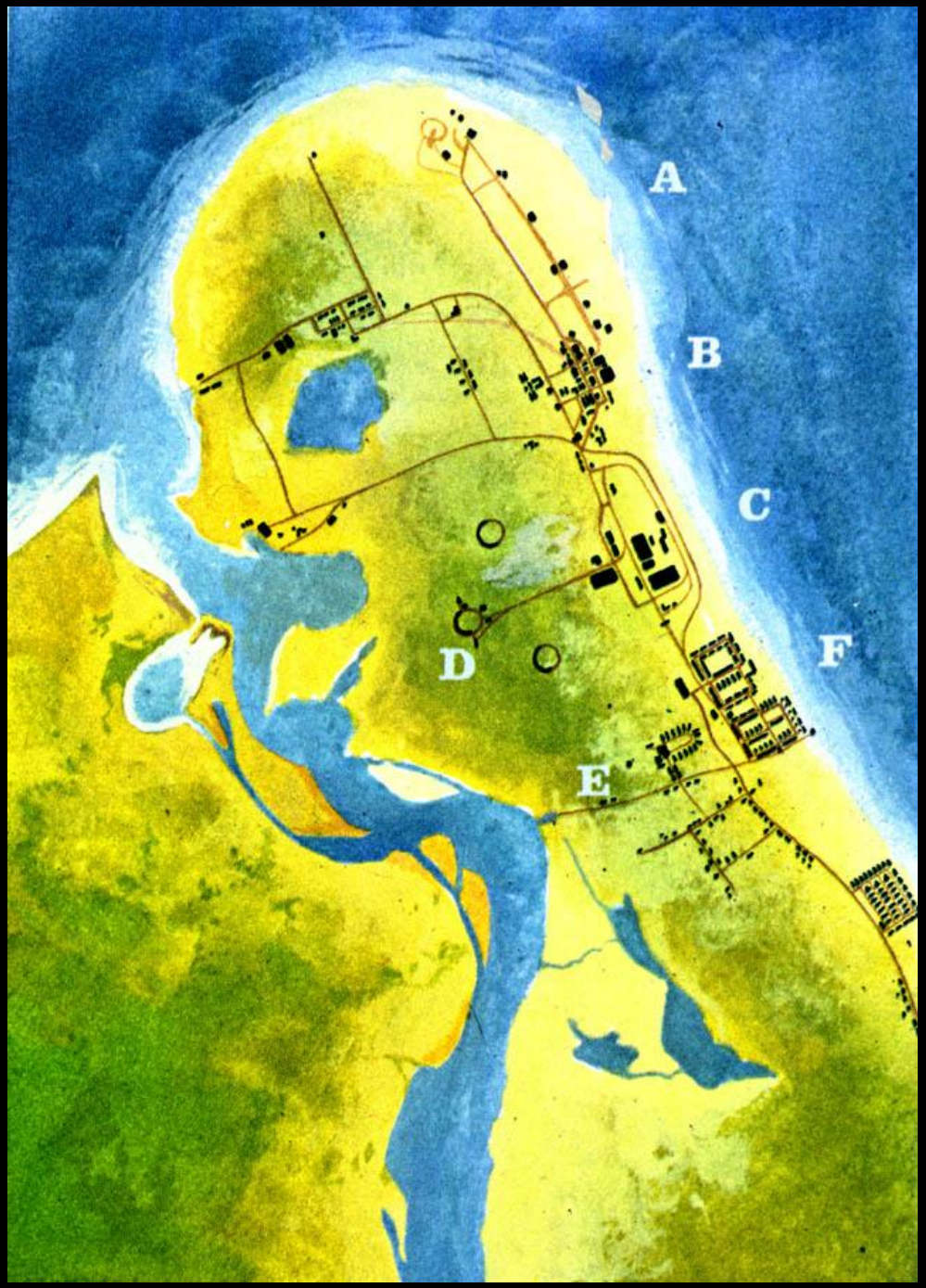
By 1932 the German Army was beginning to show an interest in the German Rocket Society's efforts, and in July of that year a Mirak rocket was launched as a demonstration for the head of the newly created German Army rocket research group, Headed by Captain Walter Dornberger.

The Mirak rocket didn't impress Dornberger but von Braun did. Three months after the Mirak flight, von Braun was engaged to work on liquid propelled rockets for the Army. Most of the German Rocket Society followed von Braun into national service and the society officially disbanded.

German Rocket Scientists Worked for Nazi War Effort

To Develop Weapon Systems Not Barred by WWI Treaties

At One Point, von Braun was Arrested and Jailed by Goebbels - Who Felt That von Braun More Interested in Rocket Science than Weapons Development

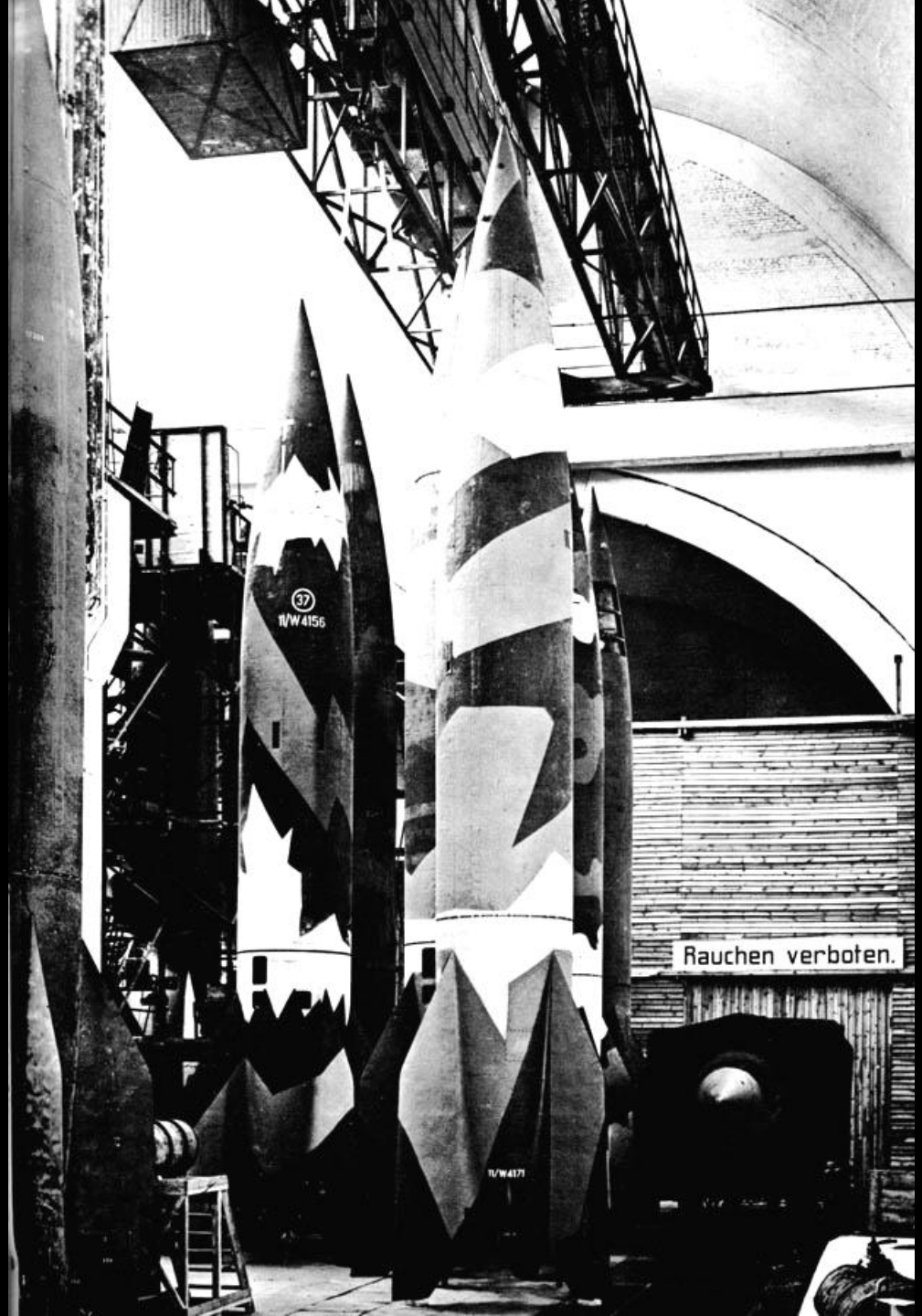


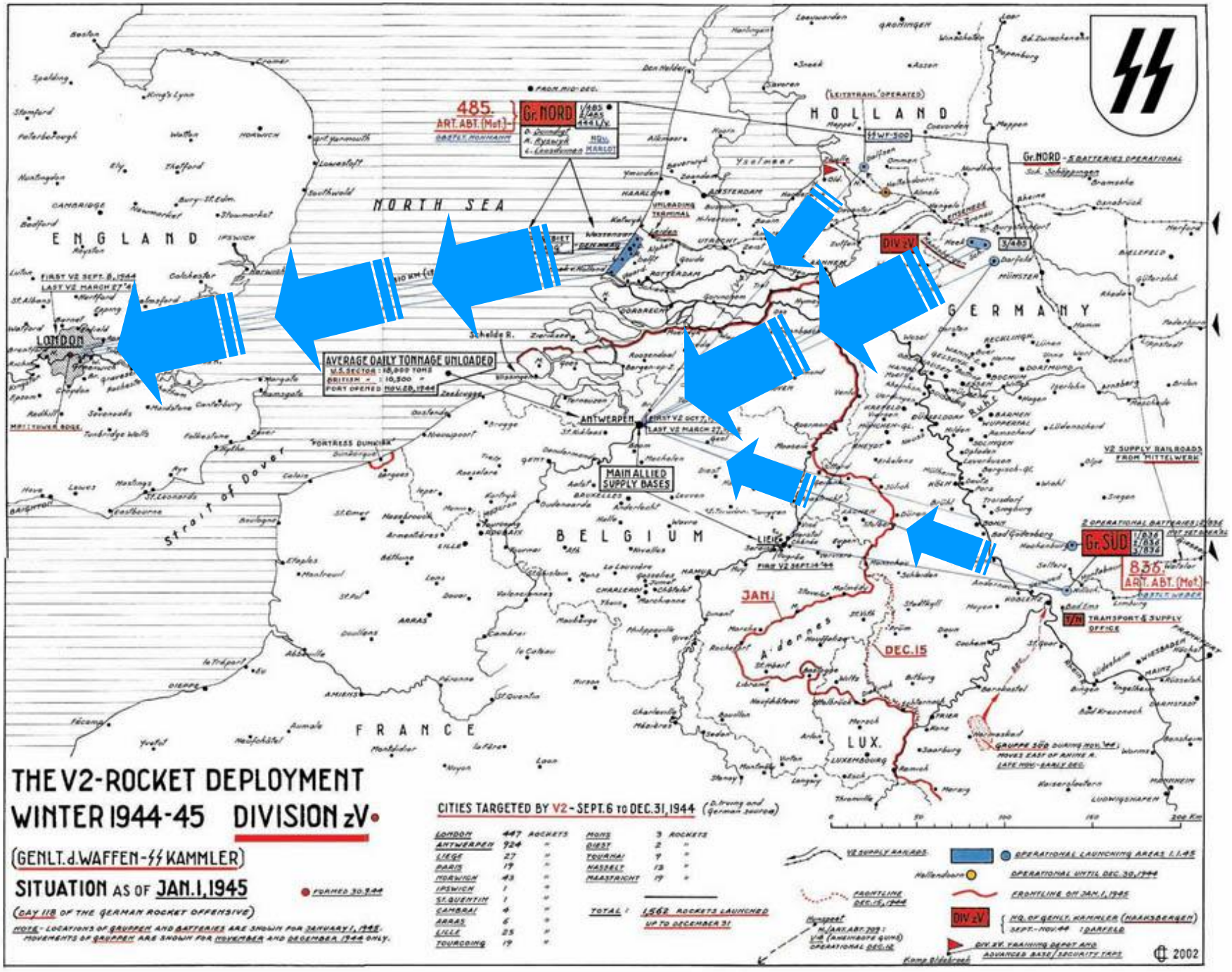
Peenemunde Rocket Facility on Baltic Coast Established 1936

A – Launch Area
B – Engineering
C – Production Plant
D - Test Stands
E – Military Camp
F – Residential Area

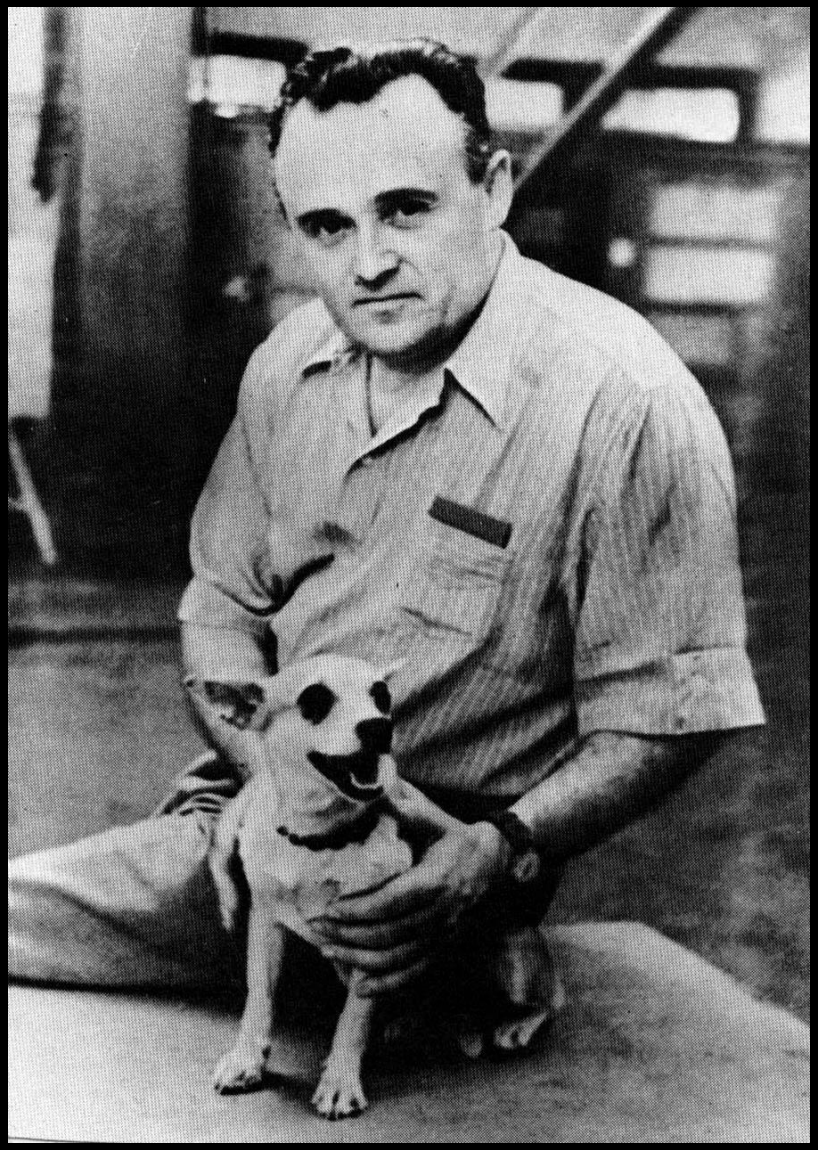
Nordhausen and Mittelwerks Rocket Depots after August 1943 British Bombing of Peenemunde

Extensive Use of POWs and Transport Tunnels




THE V2-ROCKET DEPLOYMENT
WINTER 1944-45 DIVISION zV
(GENLT. d. WAFFEN-SS KAMMLER)
SITUATION AS OF JAN. 1, 1945
(DAY 118 OF THE GERMAN ROCKET OFFENSIVE)
NOTE - LOCATIONS OF GRUPPEN AND BATTERIES ARE SHOWN FOR JANUARY 1, 1945. MOVEMENTS OF GRUPPEN ARE SHOWN FOR NOVEMBER AND DECEMBER 1944 ONLY.
FORMED 30.9.44
CITIES TARGETED BY V2 - SEPT. 6 TO DEC. 31, 1944 (D. Irving and German sources)
LONDON 447 ROCKETS
ANTWERPEN 924 "
LIEGE 27 "
PARIS 19 "
NORWICH 43 "
IPSWICH 1 "
ST. QUENTIN 1 "
CAMBRAI 4 "
ARRAS 6 "
LILLE 25 "
TOURCOING 19 "
MONS 3 ROCKETS
DIEST 2 "
TOURNAI 9 "
HASSELT 13 "
MAASTRICHT 19 "
TOTAL: 1,562 ROCKETS LAUNCHED UP TO DECEMBER 31
485. ART. ABT. (Mot.)
Gr. NORD
Gr. MORD - 5 BATTERIES OPERATIONAL
Gr. SÜD
836. ART. ABT. (Mot.)
DIV zV
HOLLAND
GERMANY
ENGLAND
BELGIUM
FRANCE
LUX.
NORTH SEA
Strait of Dover
LONDON
ANTWERPEN
LIEGE
AVERAGE DAILY TONNAGE UNLOADED
U.S. SECTOR: 18,000 TONS
BRITISH " : 10,500 "
PORT OPENED NOV. 28, 1944
MAIN ALLIED SUPPLY BASES
V2 SUPPLY RAILROADS FROM "MITTELWERK"
JAN.
DEC. 15
TRANSPORT & SUPPLY OFFICE
V2 SUPPLY RAILROADS
OPERATIONAL LAUNCHING AREAS 1.1.45
OPERATIONAL UNTIL DEC. 30, 1944
FRONTLINE ON JAN. 1, 1945
FRONTLINE DEC. 15, 1944
HQ. OF GENLT. KAMMLER (HARSBERGEN) SEPT.-NOV. 44 : DARFELD
DIV zV TRAINING DEPOT AND ADVANCED BASE/SECURITY TROOPS
© 2002

Sergei Pavlovich Korolev (1907-1966)



Grand Designer
Soviet Rocket Program

1954 – Soviet Planning for IGY Prompted Scientific Paper on Satellites by Korlev

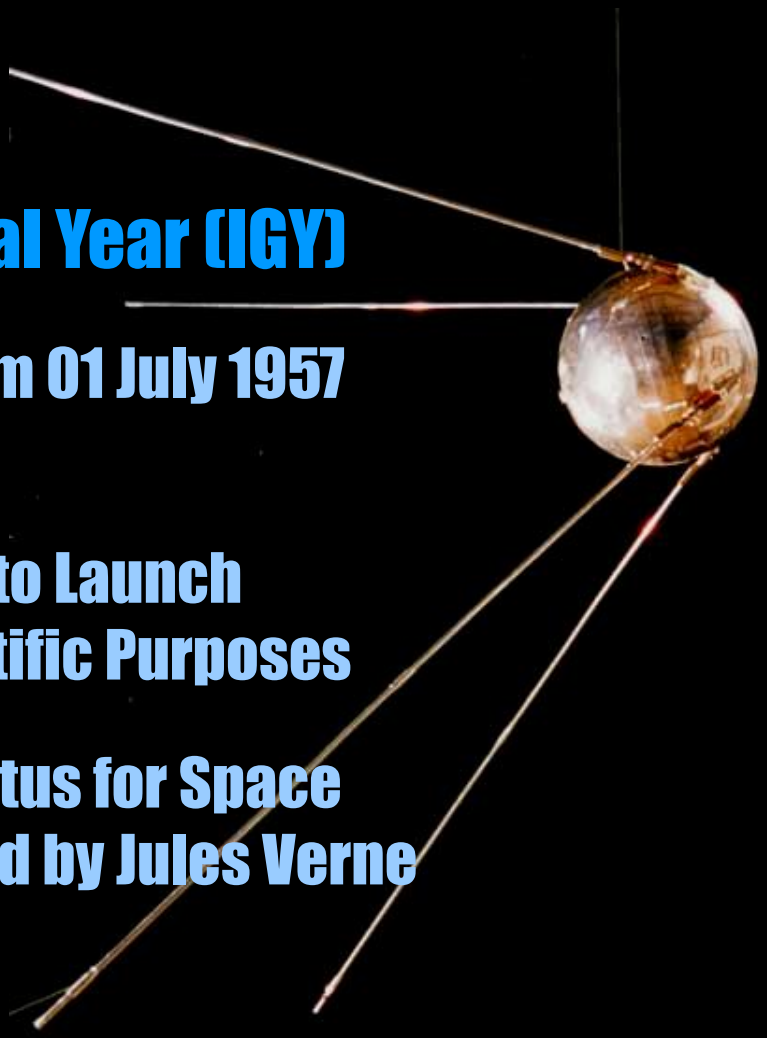
1955 – Soviet Academy of Sciences, inspired by Korolev's paper, meet to create "Commission for Interplanetary Travel"

1955 – On 29 August Korolev Submits Plans for a Satellite to the Soviet Leadership for IGY

V-2 Rocket
Captured by Americans at Peenemunde

Launched from White Sands, NM 1946

The IGY Satellite Race



International Geophysical Year (IGY)

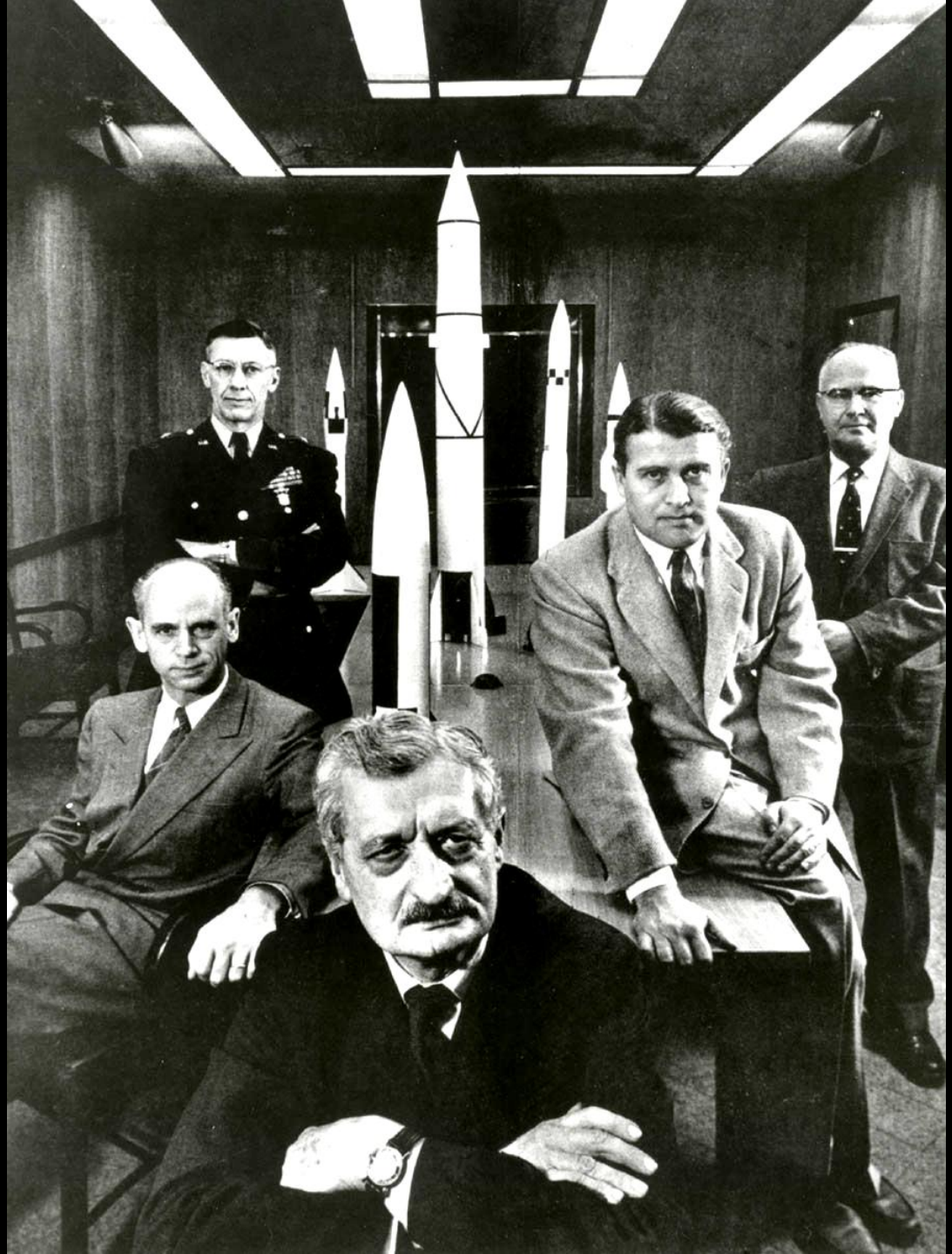
Actually a year and a half from 01 July 1957 to 31 December 1958

Global Agreement and Effort to Launch Satellites for Peaceful Scientific Purposes

Yet, Underlying Military Impetus for Space Programs, as originally stated by Jules Verne in 1865

1958

ABMA - Huntsville, AL



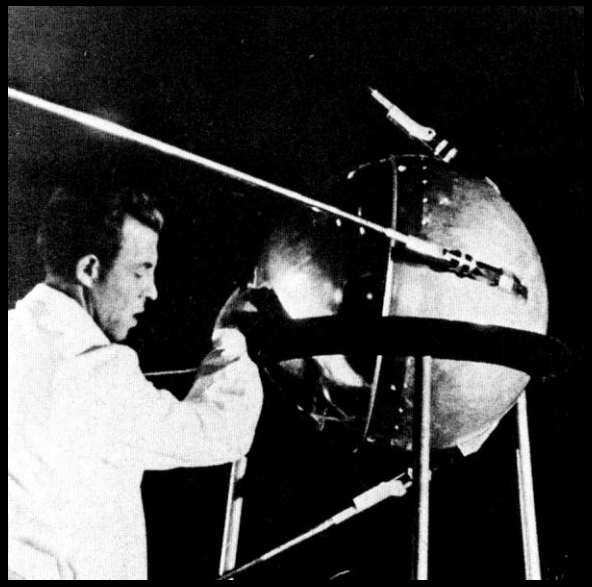
Col. Rees
von Braun
Stuhlinger
Torkoy
Oberth

ABMA
1957

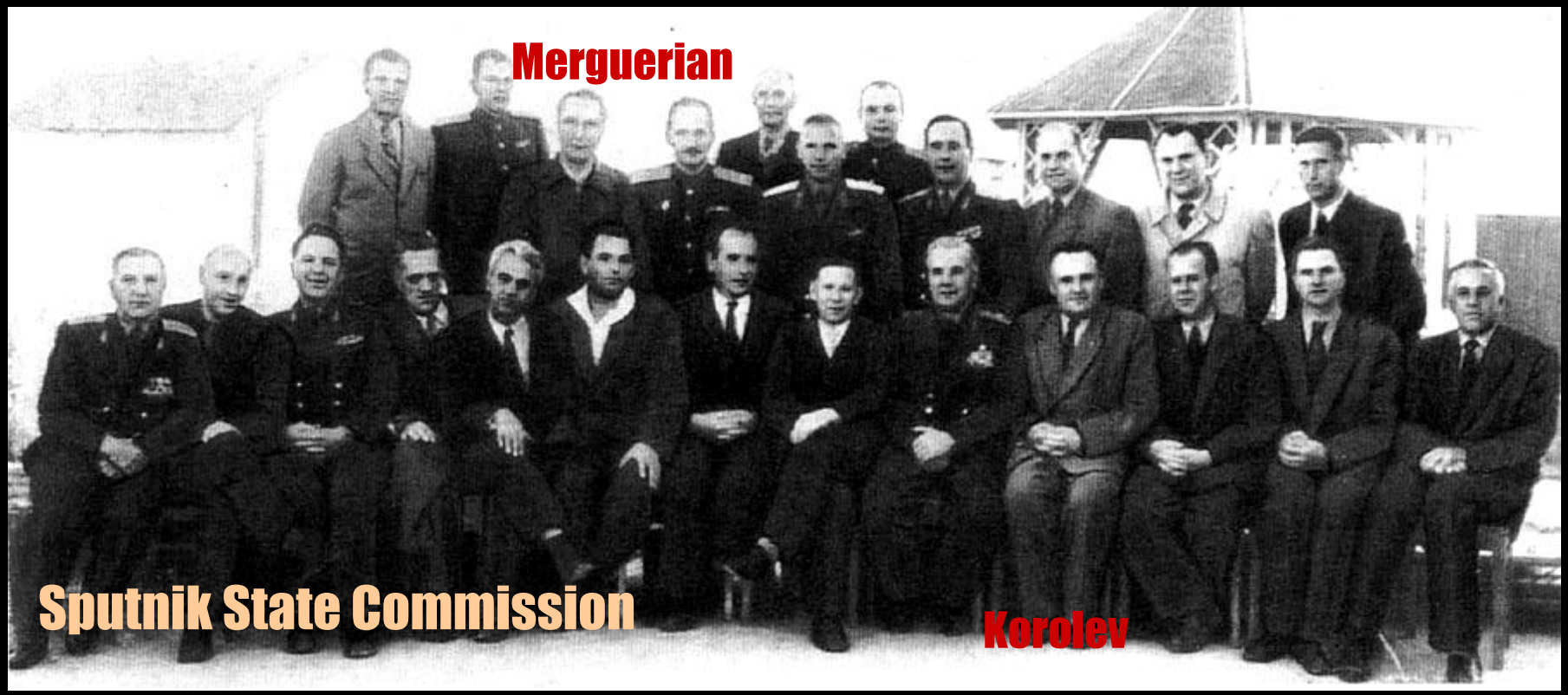
Who's In Charge Here?

By 1955, the U.S. Navy was charged with developing their Vanguard Program to launch first U.S. satellite

NACA (National Advisory Committee For Aeronautics) became NASA in 1958



Sputnik 1 "Fellow Traveler"
Launched 04 Oct 1957
First Artificial Satellite
185#, Diameter 23"



"All the News That's Fit to Print"

The New York Times.

LATE CITY EDITION

VOL. CVII...No. 36,026. NEW YORK, SATURDAY, OCTOBER 5, 1957. FIVE CENTS

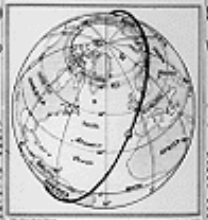
SOVIET FIRES EARTH SATELLITE INTO SPACE; IT IS CIRCLING THE GLOBE AT 18,000 M. P. H.; SPHERE TRACKED IN 4 CROSSINGS OVER U. S.

HOFFA IS ELECTED TEAMSTERS' HEAD; WARNS OF BATTLE

Defeats Two Foes 3 to 1 —Says Union Will Fight 'With Every Ounce'

COURSE RECORDED

Navy Picks Up Radio Signals—4 Report Sighting Device



560 MILES HIGH

Visible With Simple Binoculars, Moscow Statement Says

Device Is 8 Times Heavier Than One Planned by U.S.

SATELLITE SIGNAL BROADCAST HERE

Impulse Carried on Radio and TV—First Reported by Long Island Station

FAUBUS COMPARES HIS STAND TO LEE'S

Says He Will Remain Loyal to People of Arkansas—All Is Quiet at School

Flu Widens in City; 10% Rate Predicted; 200,000 Pupils Out

ARGENTINA TAKES EMERGENCY STEPS

State of Siege Proclaimed in Buenos Aires Region —Arrests Reported

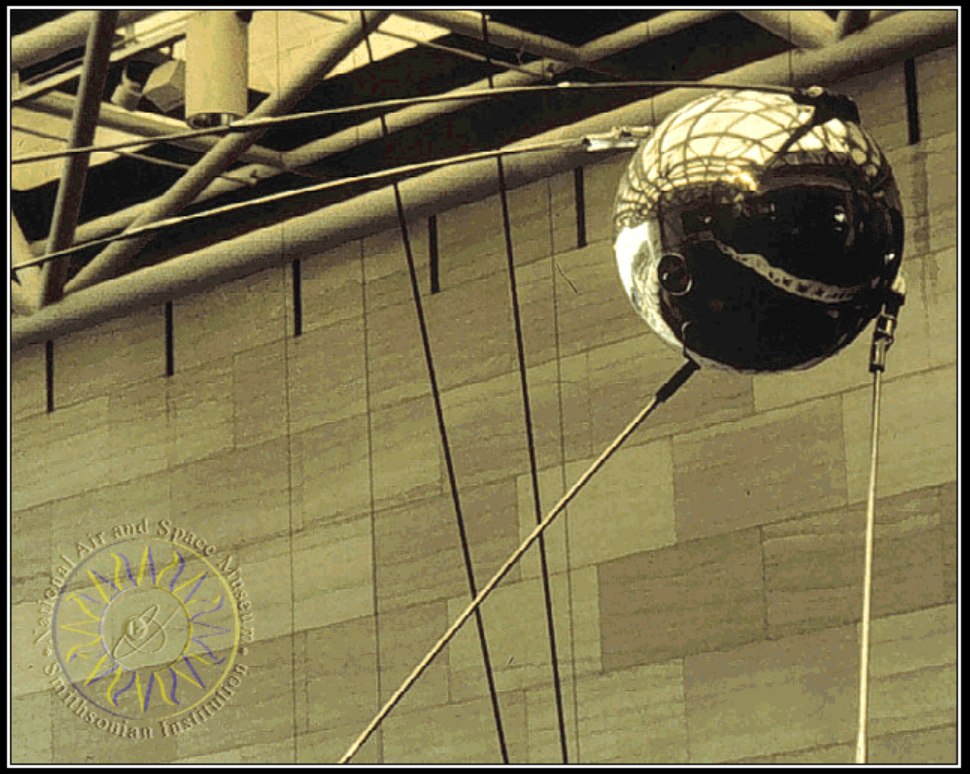
Ex-Premier Mollet Accepts Bid To Form a New French Cabinet

Socialist Leader Agrees With Reluctance and Without Going Past Rue

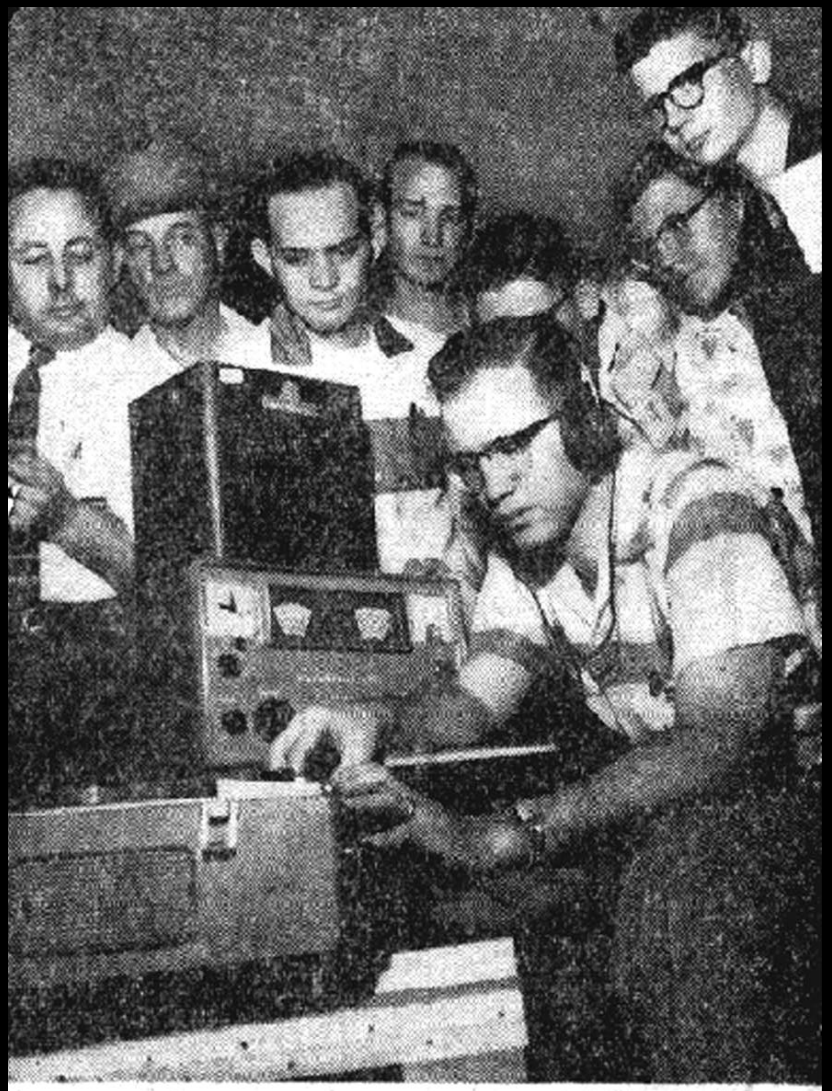
Guy Mollet

City Sifts Charge That Schuyler, Brooklyn Councilman, Sold a Job

Warsaw Crushes New Protest; Clubs, Tear Gas Rout Students



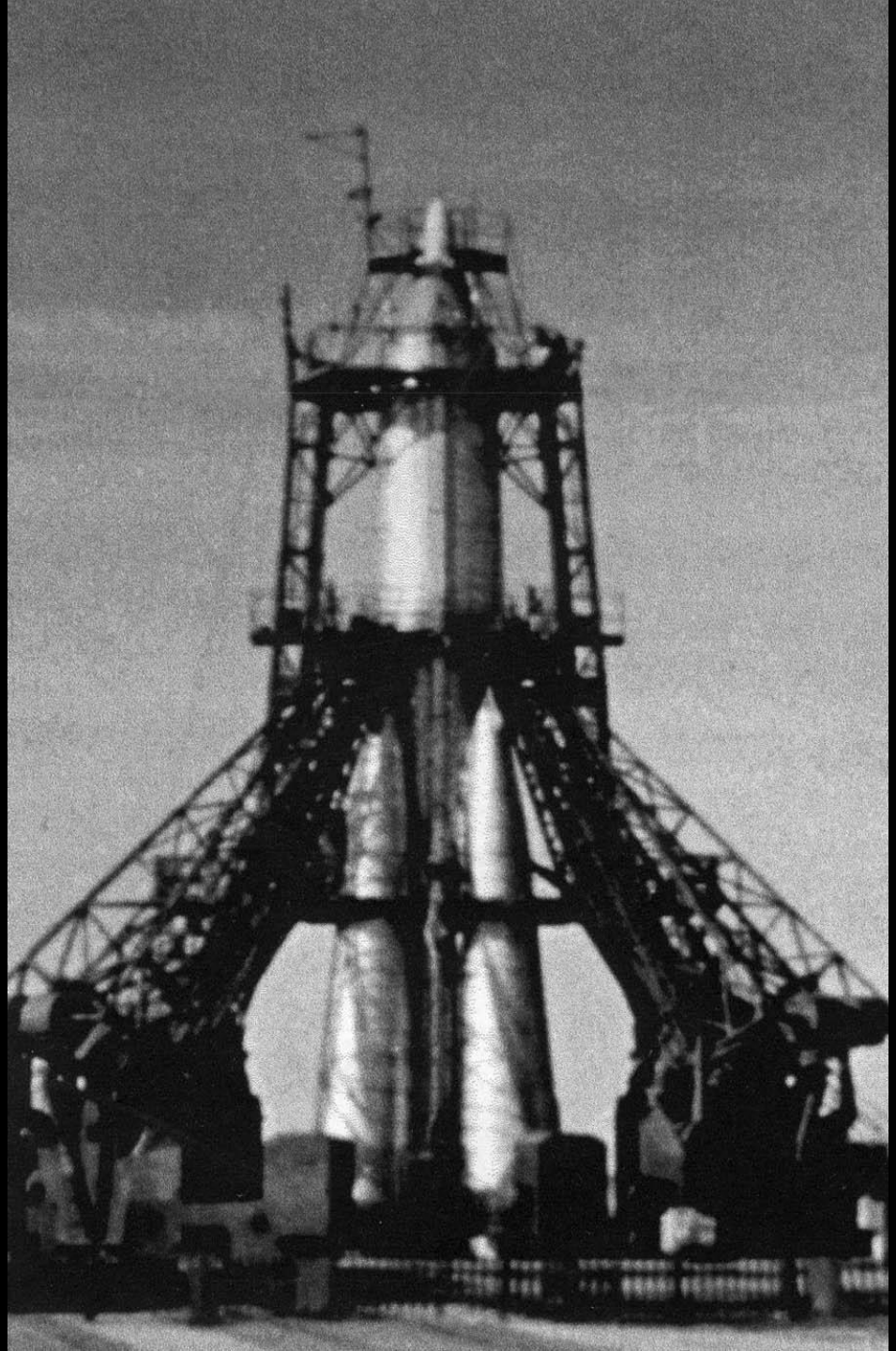
Clever Marketing Ploy as Sputnik Signals on Ham Radio Frequency



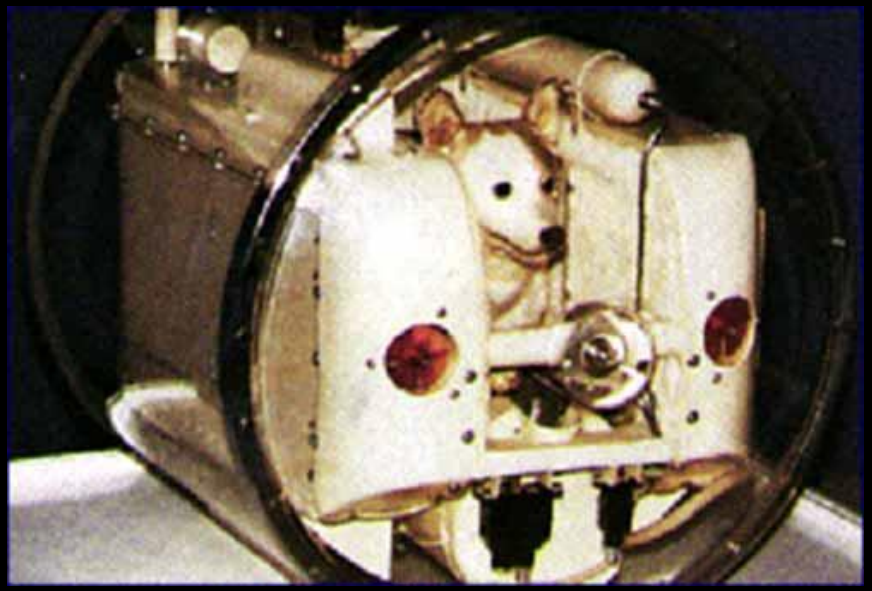
—Dallas News Staff Photo.

SIGNALS FROM THE SATELLITE

Ham operator Roy Welch of Dallas, seated, plays a tape-recorded signal from the Russian space satellite for fellow hams at the State Fair of Texas. Welch recorded the signals on a receiver at his home.



Sputnik 2 Laika
03 Nov 1957



Massive Satellite
Weighed 1,120 Pounds
Proved Soviets Capable of
Launching Heavy Payloads

By 1957, the Soviets had big ICBMs –
U.S. had yet to test the far smaller Atlas.

The Soviets had the glory of launching the Space Age - a vast gain in prestige for the Communists and morale blow to the West.

If the Soviet ICBM was reliable and effective and put into mass production, and if the Americans failed to catch up or take vital counteractions, the Soviets might gain a first-strike capability within a few years.

Vanguard I Explosion

06 Dec 1957

Hopes of American Space Program Topple along with Cracked Nose Cone of Navy Vanguard Missile

31 Jan 1958

Successful Launch of Explorer I on a U.S. Army Jupiter-C (V-2 Design)

In Less Than 2 Months Retooled Launch Facility at Cape for an off-the-shelf Redstone – Launch Vehicle 29 (UE)

SATELLITE EXTRA ★★★ ★★★

The Huntsville Times

SATELLITE EXTRA ★★★ ★★★

HUNTSVILLE, ALABAMA, SATURDAY, FEB. 1, 1958

Jupiter-C Puts Up Moon

Eisenhower Officially Announces Huntsville Satellite Circles Globe

Wail Of Sirens Brings In Era On Space Here

Thousands Gather On The Square For Noisy Success Demonstration

9 Labs Here Aided Project Of Launching

It Took Every One To Successfully Put Up 'Moon' Vehicle

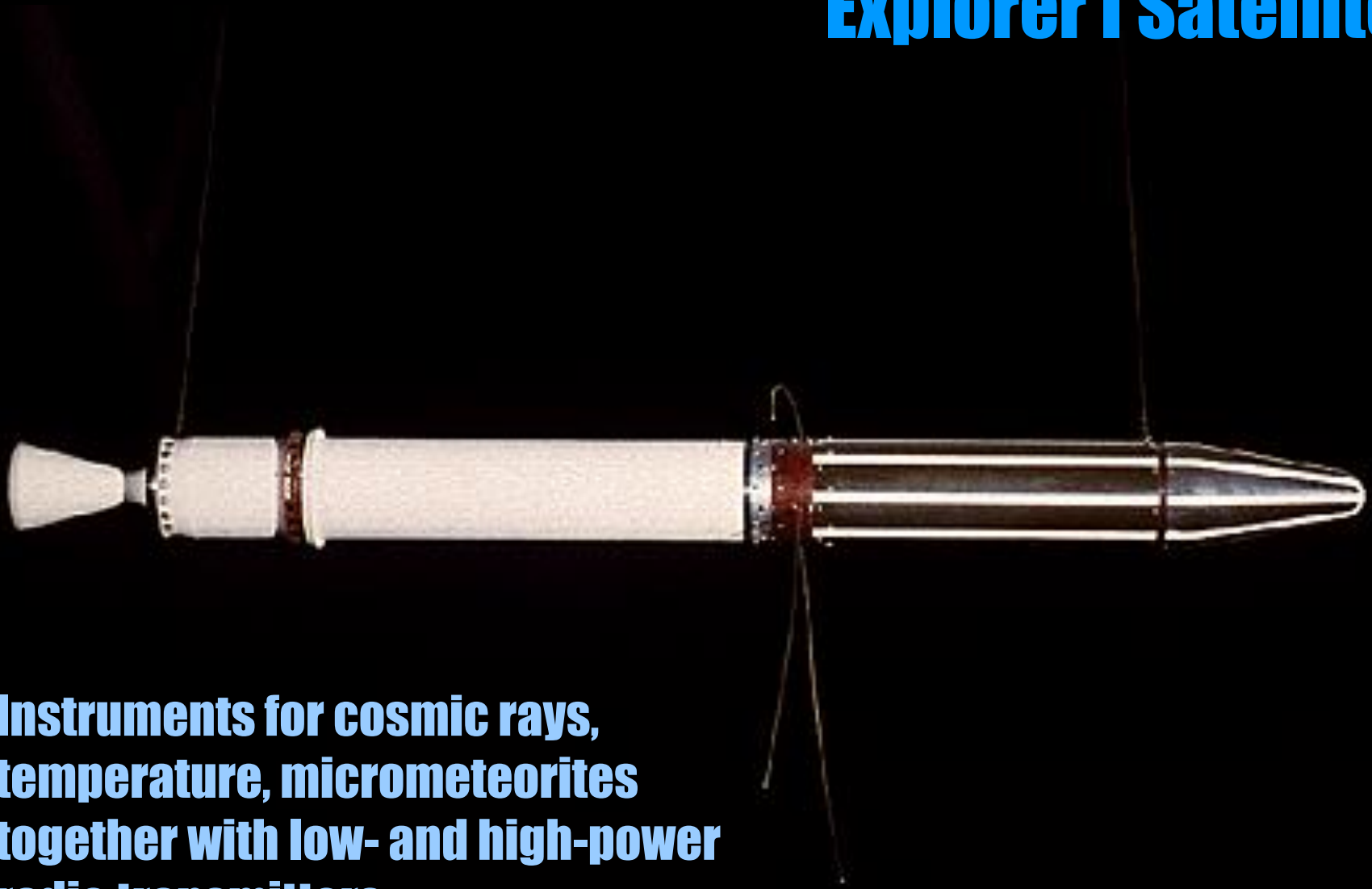
Weather Change Sped Launching

* * *

Army Reveals Second Moon Is Scheduled

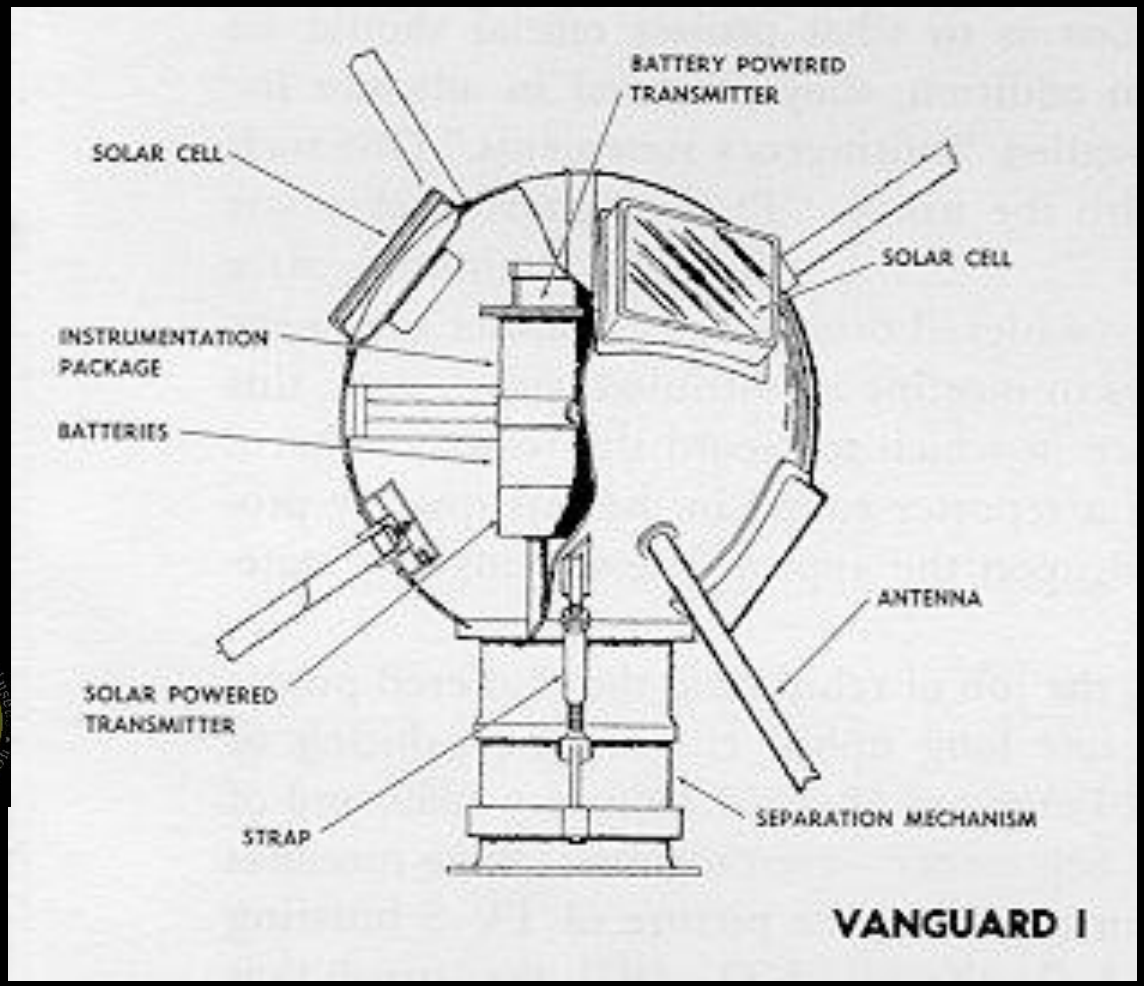
70-Foot Carrier Roars Into Starry Night At Cape Canaveral

Explorer I Satellite

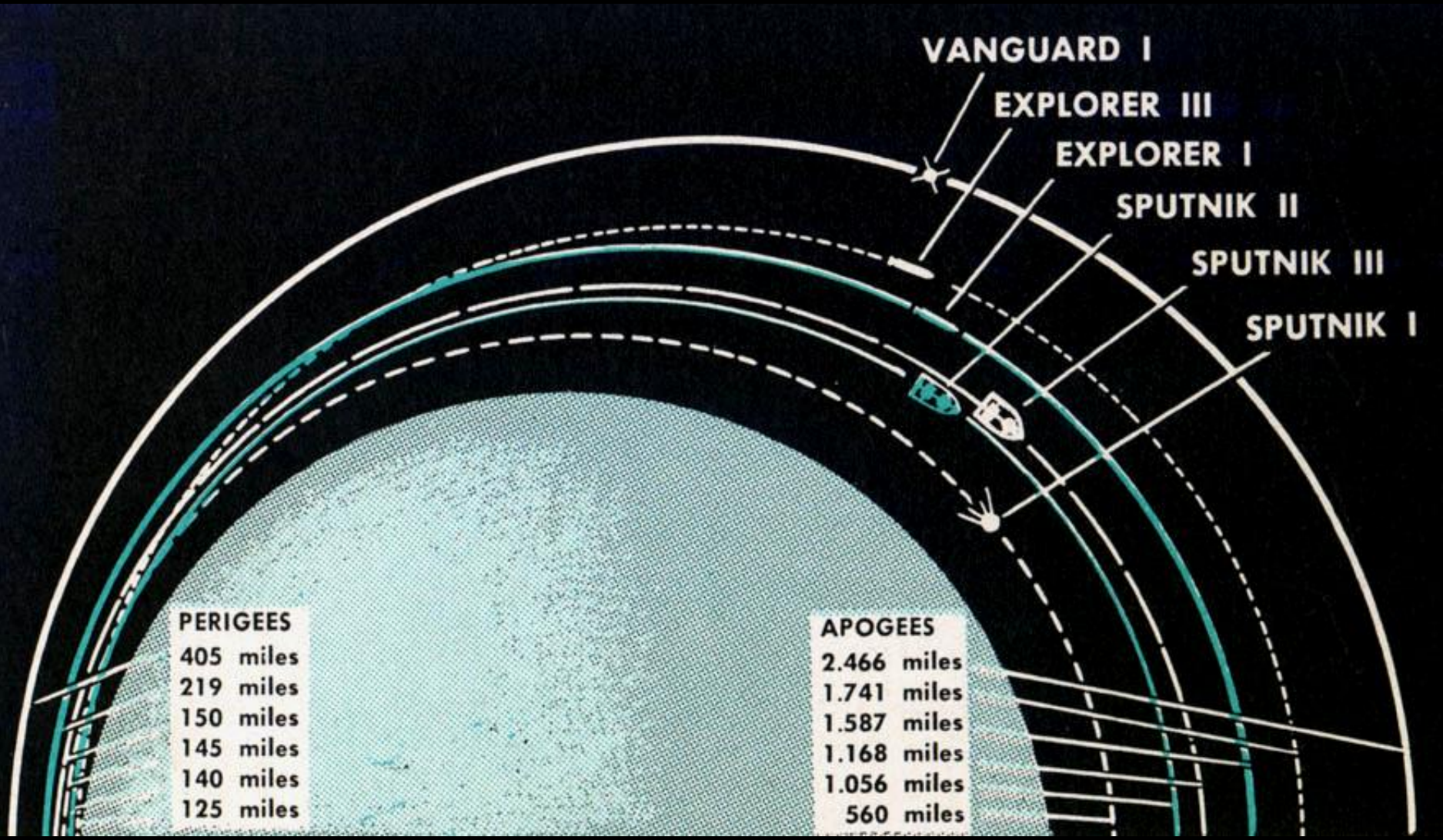


Instruments for cosmic rays, temperature, micrometeorites together with low- and high-power radio transmitters

Vanguard I
17 March 1958

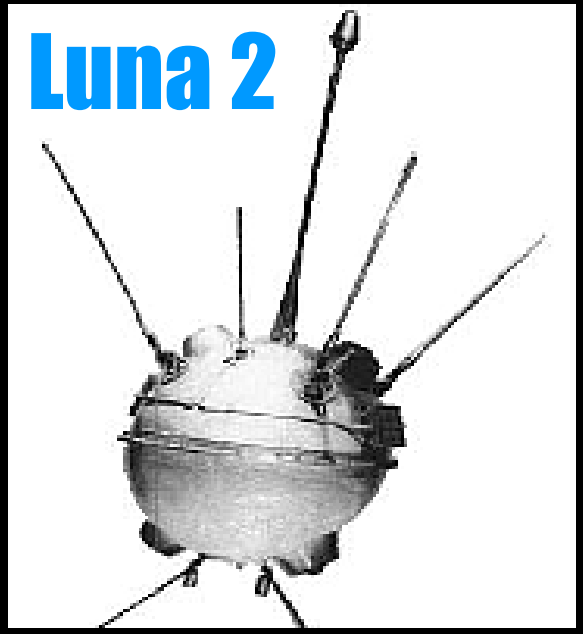


IGY Satellite Orbits

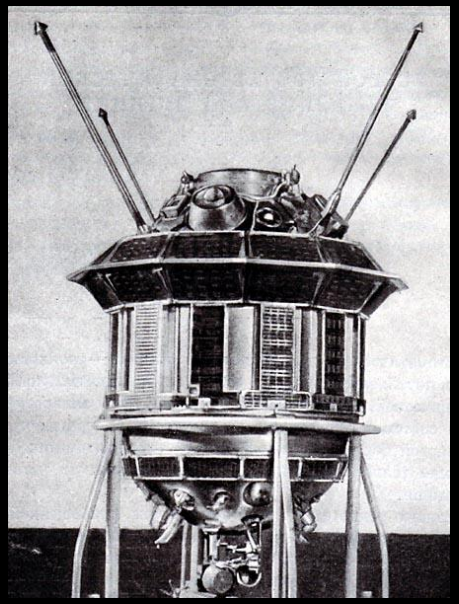


Luna 1

Luna 2



Luna 3



Soviet Luna Program 1959-1969

02 Jan 1959 – Luna 1 (Bypassed Moon 4,600 mi)

12 Sep 1959 – Luna 2 (Lunar Impact)

04 Oct 1959 – Luna 3 (Circum Lunar Orbit – First Images of Lunar Far Side)

02 Apr 1963 – Luna 4 (Bypassed Moon by 4,300 mi)*

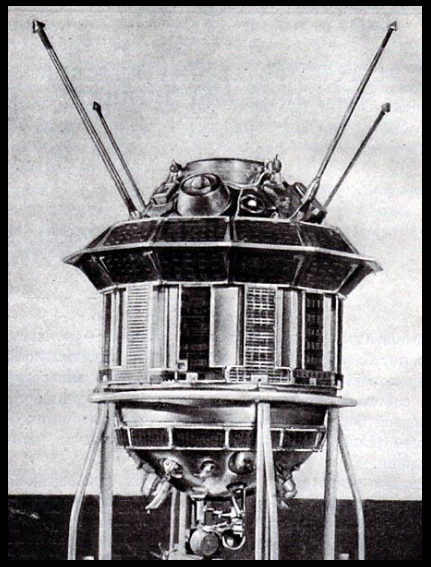
09 May 1965 – Luna 5 (Impacted on Lunar Surface)*

08 Jun 1965 – Luna 6 (Bypassed Moon)*

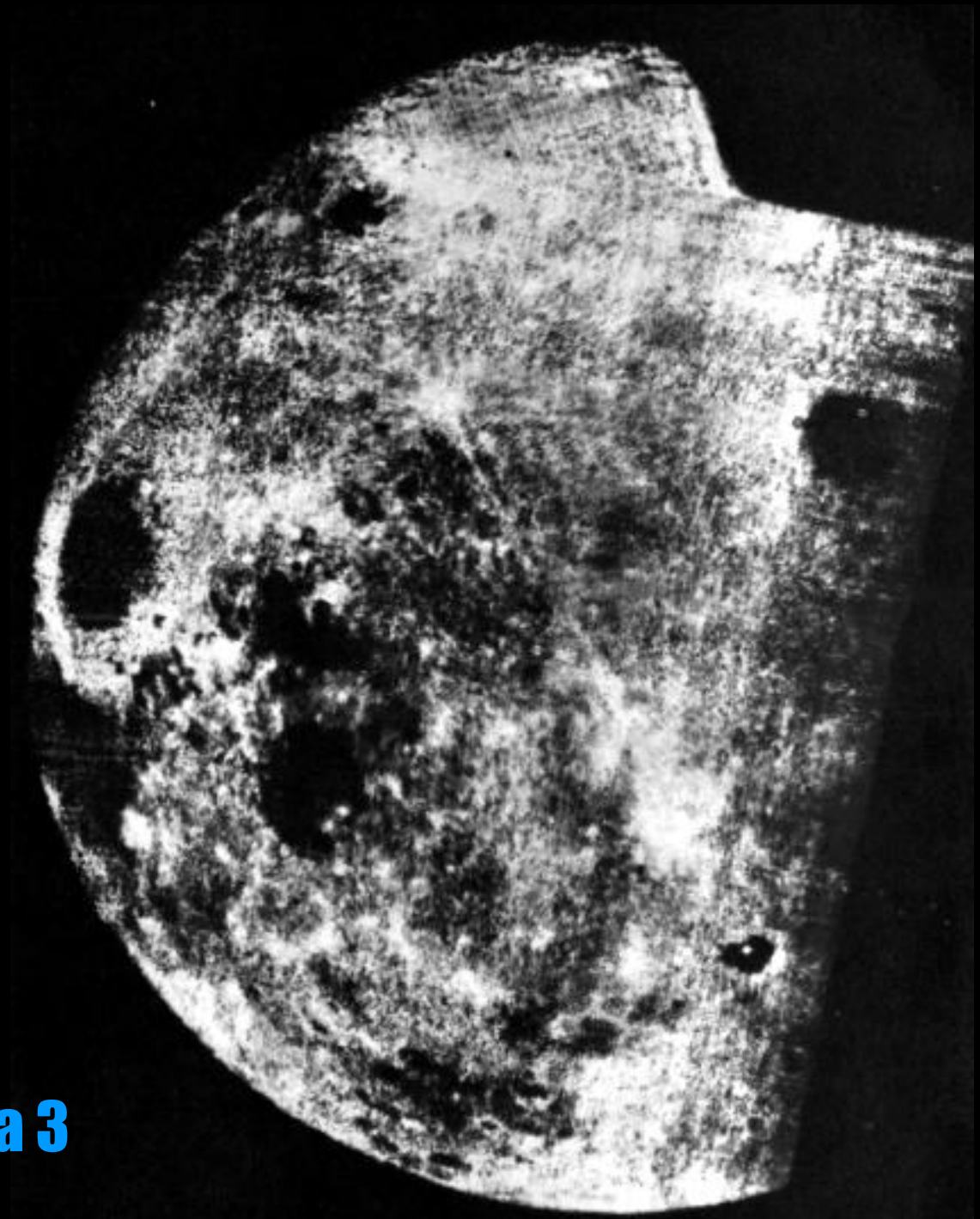
* = Unsuccessful

Luna 3
04 Oct 1959

Two Years After Sputnik I – First Human View of Lunar Farside



Luna 3



Yuri Gagarin

1935-1968

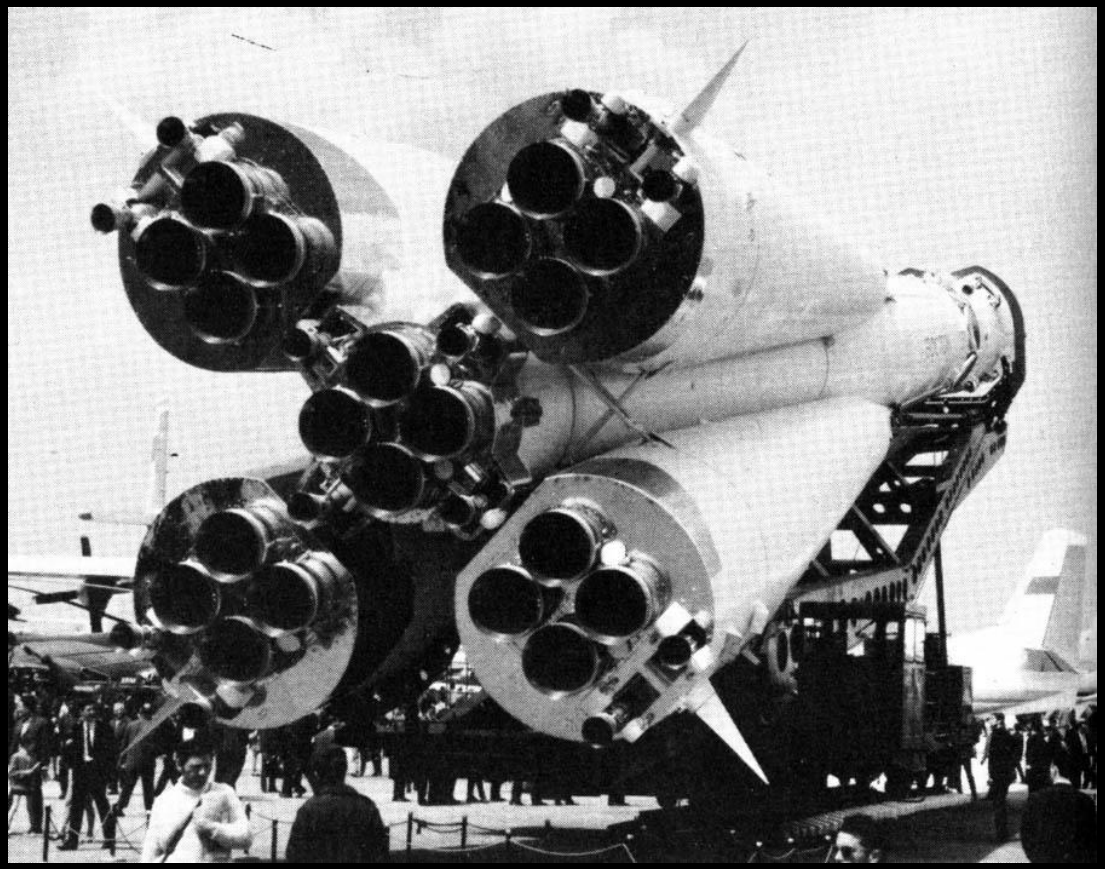
First Human
to Orbit
Earth
(One Orbit)

---

12 Apr 1961

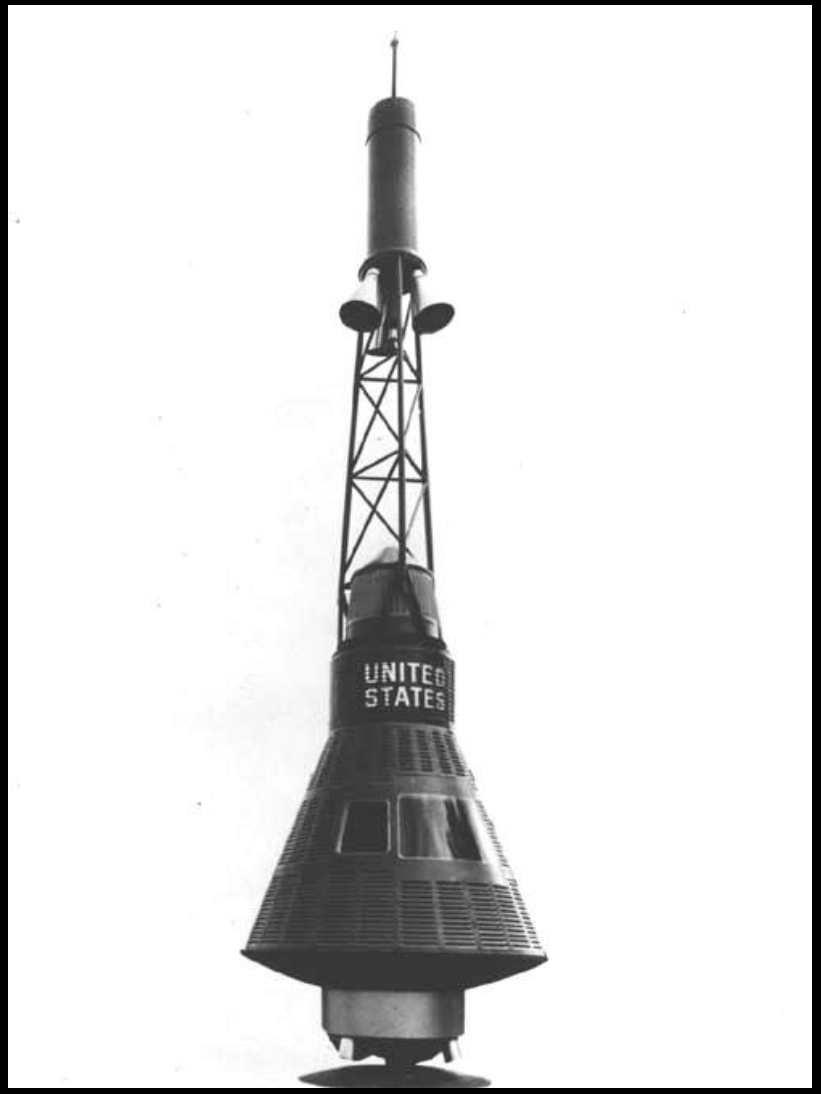
Vostok 1 Mission
Kedr Spacecraft

Gagarin Vostok Booster



Ironically, on 27 March 1968 he and his flight instructor died in a MIG-15UTI "Fagot" on a routine training flight near Kirzhach

Mercury Program 1958-1963



Alan Shepard

1923-1998

Second Human into Space (Suborbital)

05 May 1961

Mercury 3 Mission

Freedom 7 Craft

"Light the Candle"

Shepard Suborbital Splashdown Rescue
05 May 1961

President John F. Kennedy

12 Sept 1962

Rice University
Houston, TX

"We choose to go to the Moon in this decade and do the other things, not because they are easy, but because they are hard."

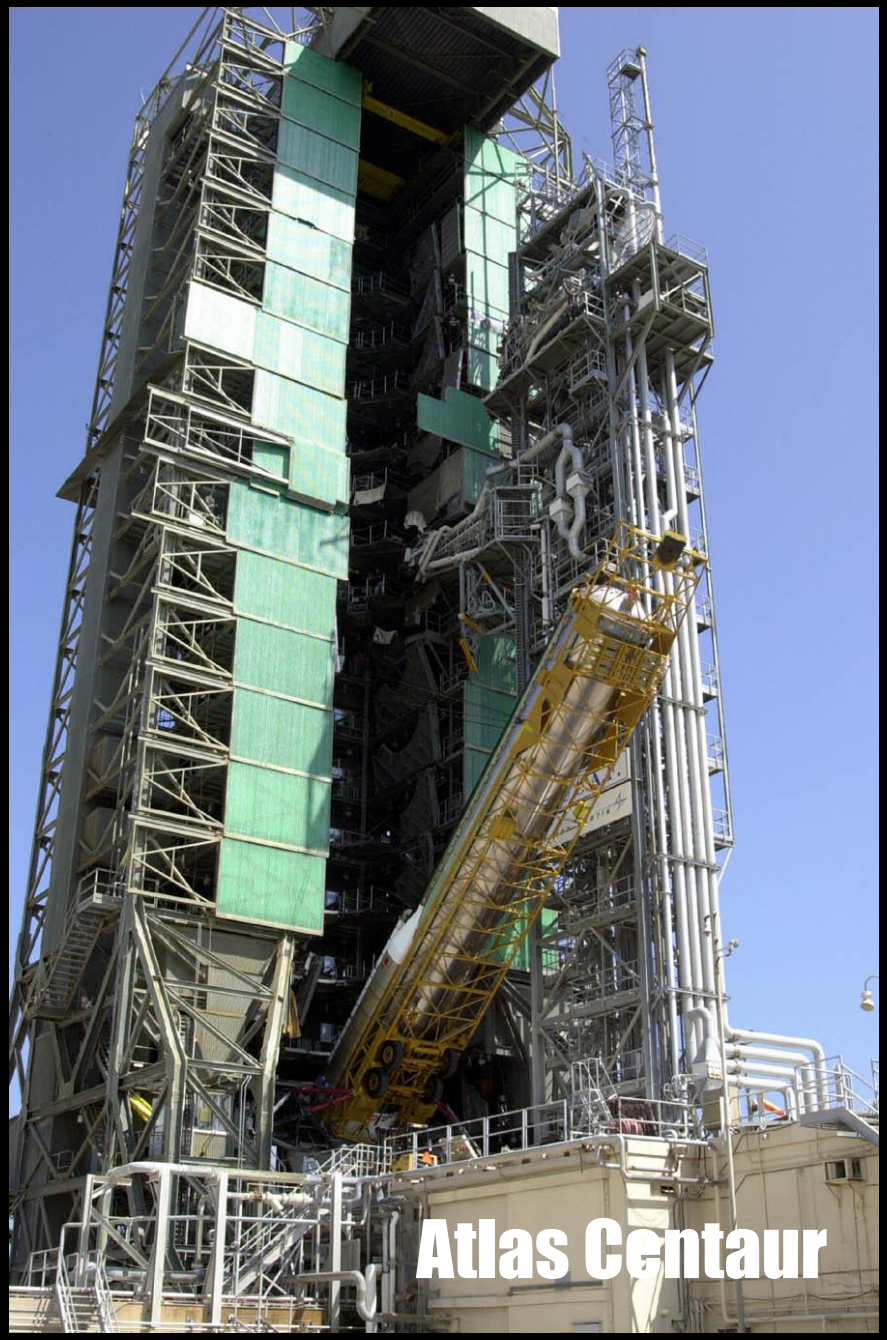
Stated to Congress in May 1961

Project Ranger
(1961-1965)

26 Jan 1962 – Ranger 3*
23 Apr 1962 – Ranger 4*
18 Oct 1962 – Ranger 5*
30 Jan 1964 – Ranger 6*
28 Jul 1964 – Ranger 7
17 Feb 1965 – Ranger 8
21 Mar 1965 – Ranger 9

Hard landings for imaging and testing of lunar surface

* = Unsuccessful



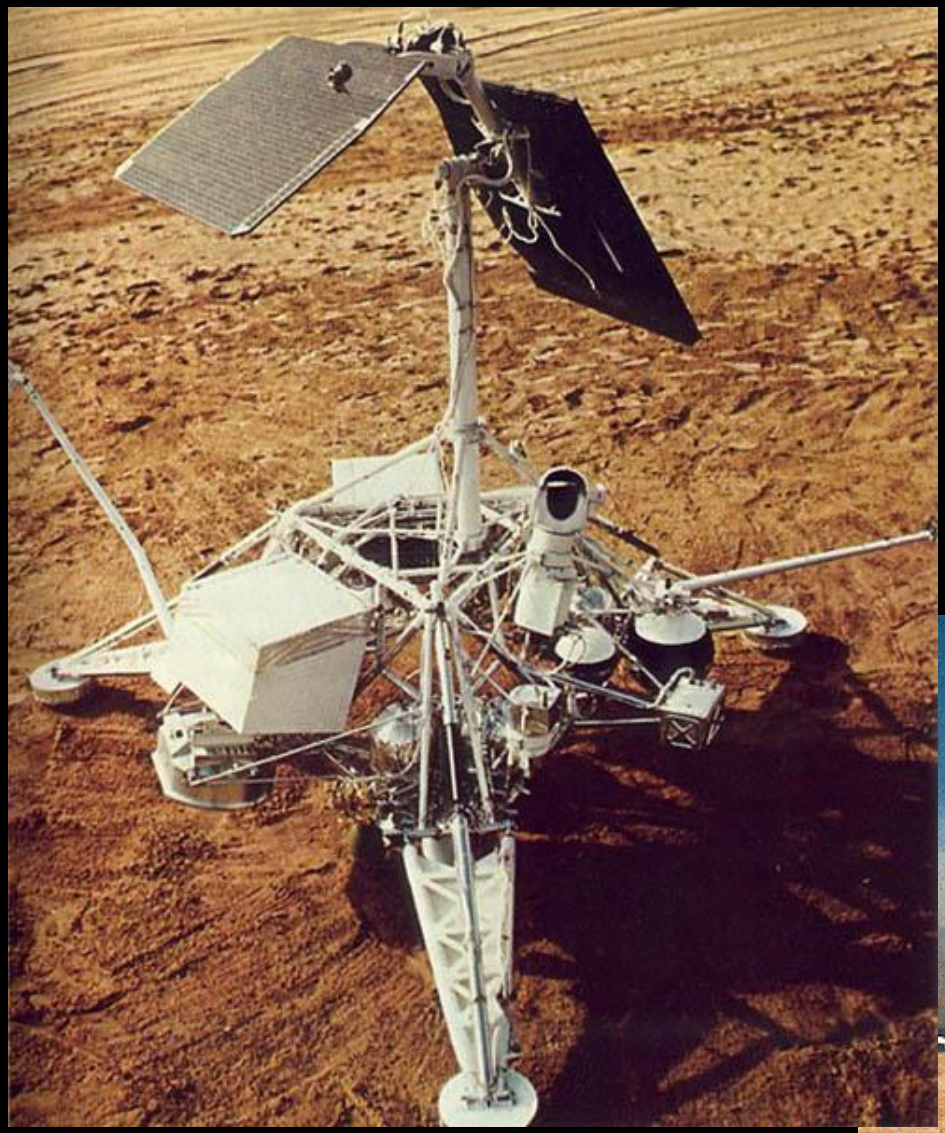
Lunar Surveyor Program (1966-1968)

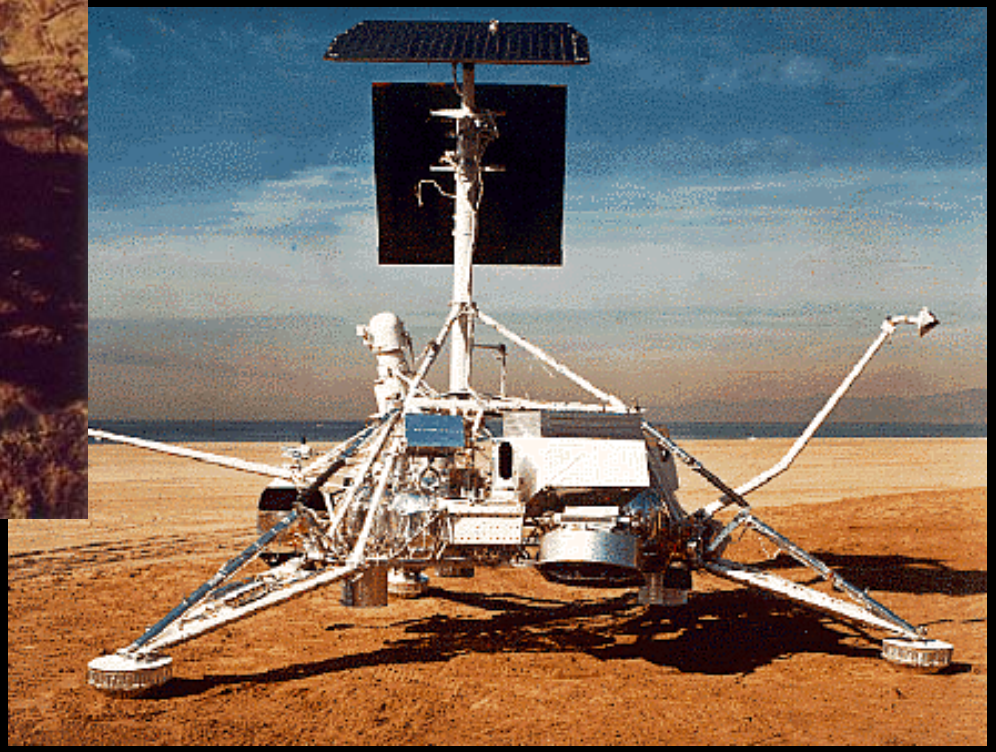
30 May 1966 – Surveyor 1
20 September 1966 – Surveyor 2*
17 April 1967 – Surveyor 3
14 Jul 1967 – Surveyor 4*
08 Sep 1967 – Surveyor 5
07 Nov 1967 – Surveyor 6
07 Jan 1968 – Surveyor 7

Soft landing for imaging and testing of lunar surface for Apollo missions

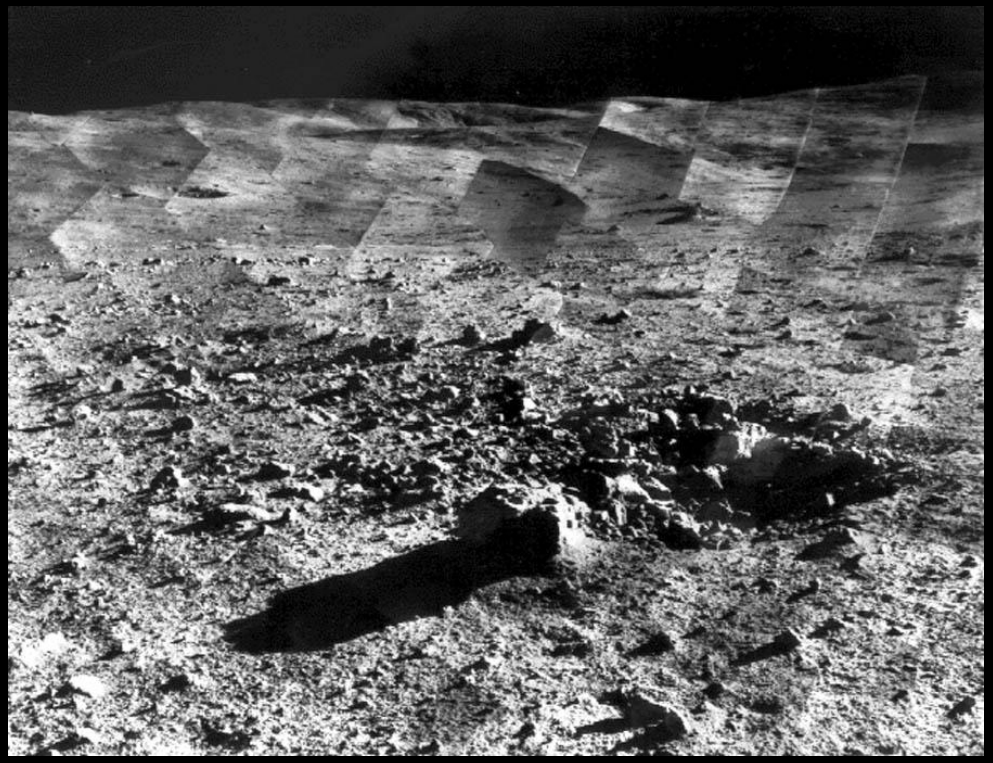
* = Unsuccessful

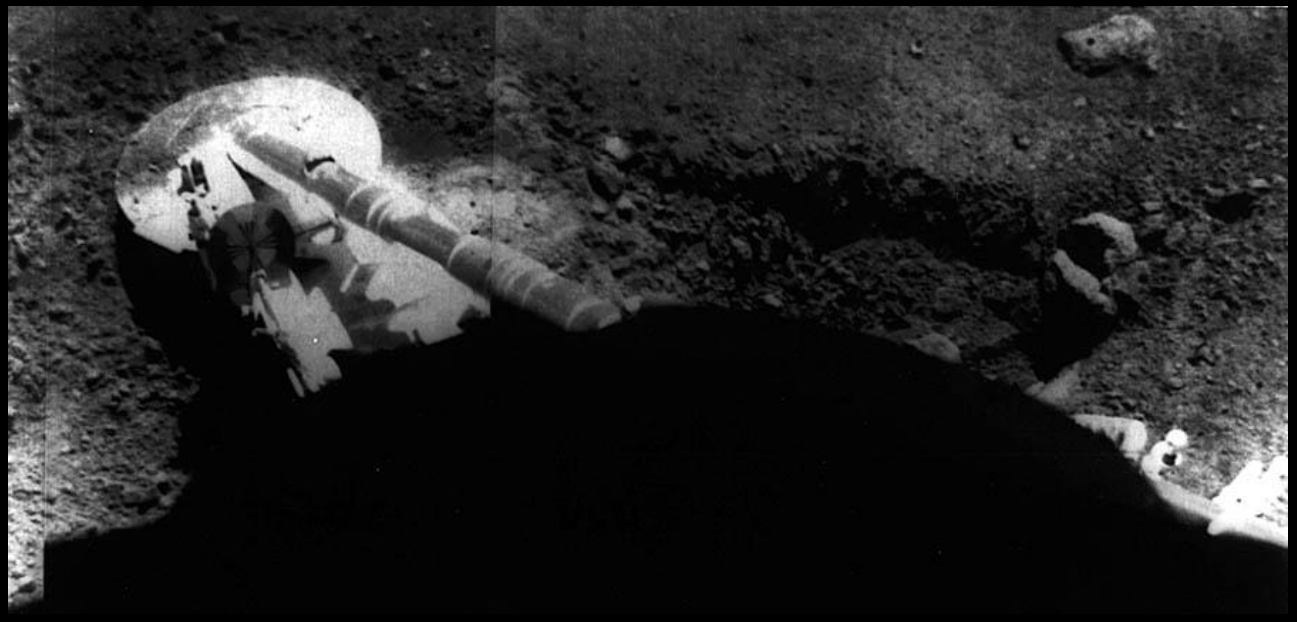
Lunar Surveyor Spacecraft





Lunar Surveyor Images from the Moon's Surface





Program Developed Soft-Landing Capability

Lunar Orbiter Program (1966-1967)

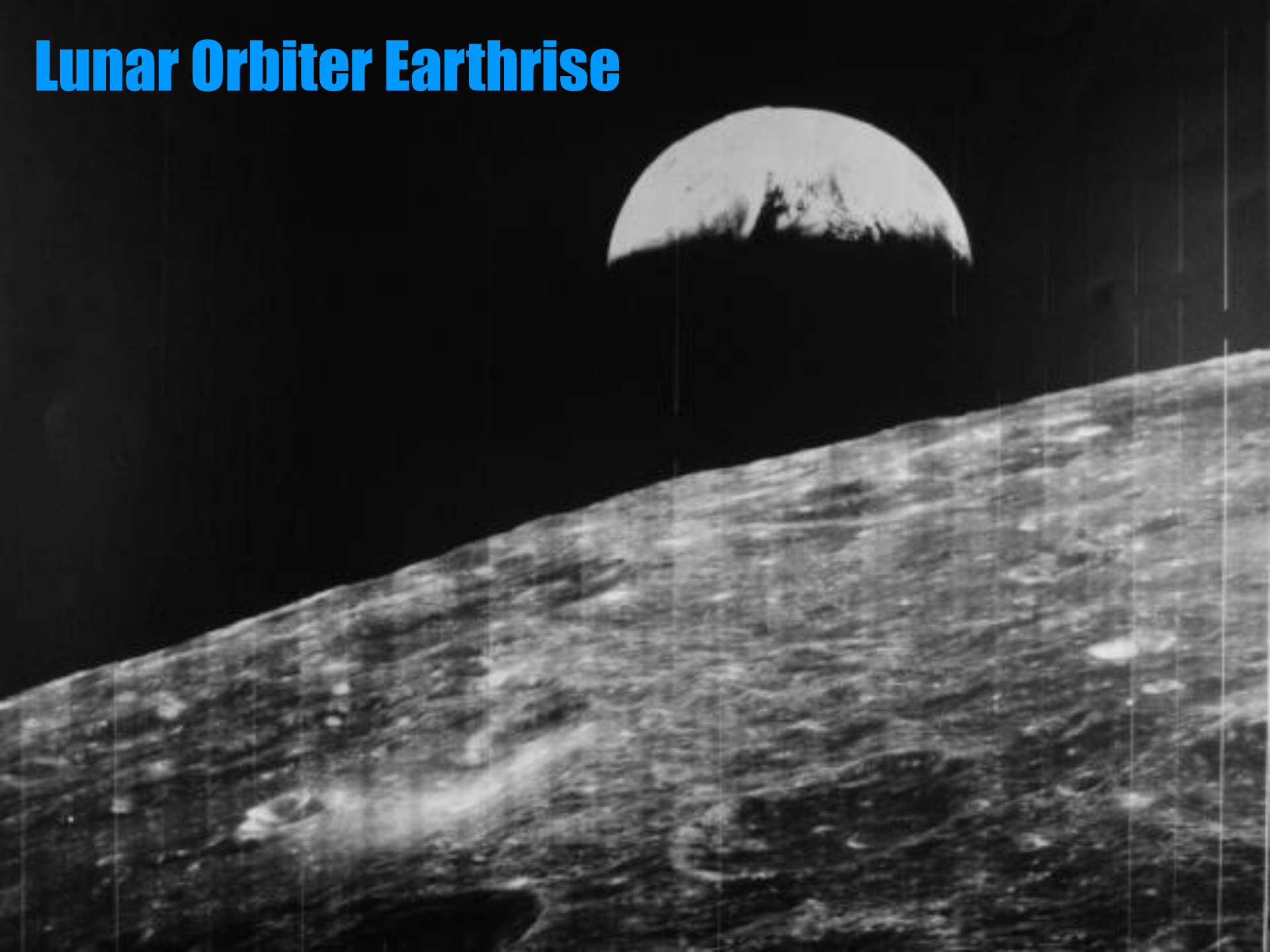
10 Aug 1966 – Orbiter 1
06 Nov 1966 – Orbiter 2
04 Feb 1967 – Orbiter 3
04 May 1967 – Orbiter 4
01 Aug 1967 – Orbiter 5

Imaging and mapping of lunar surface to focus Apollo missions

All Successful

Orbiter on Atlas Agena D

Lunar Orbiter Earthrise




Lunar Orbiter Tycho
~108 Ma

Lunar Orbiter
Orientale Basin

Apollo 8 – “Earthrise”

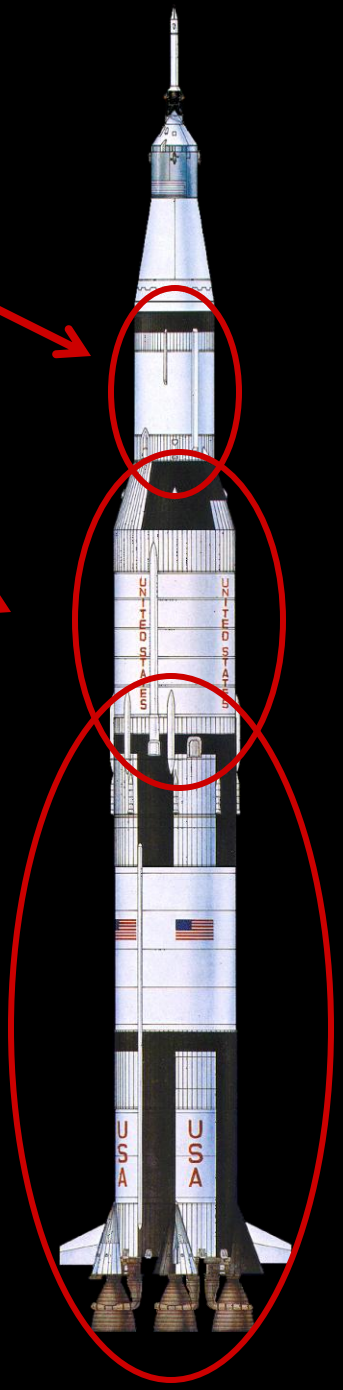
Dec 1968

Saturn V Moon Rocket

Vehicle AS-505
363’ in Height
33’ Wide
6,391,120# Curb Weight

Engine Thrust:

S-1C = 7,680,000#
S-2 = 1,150,000#
S-4B = 230,000#

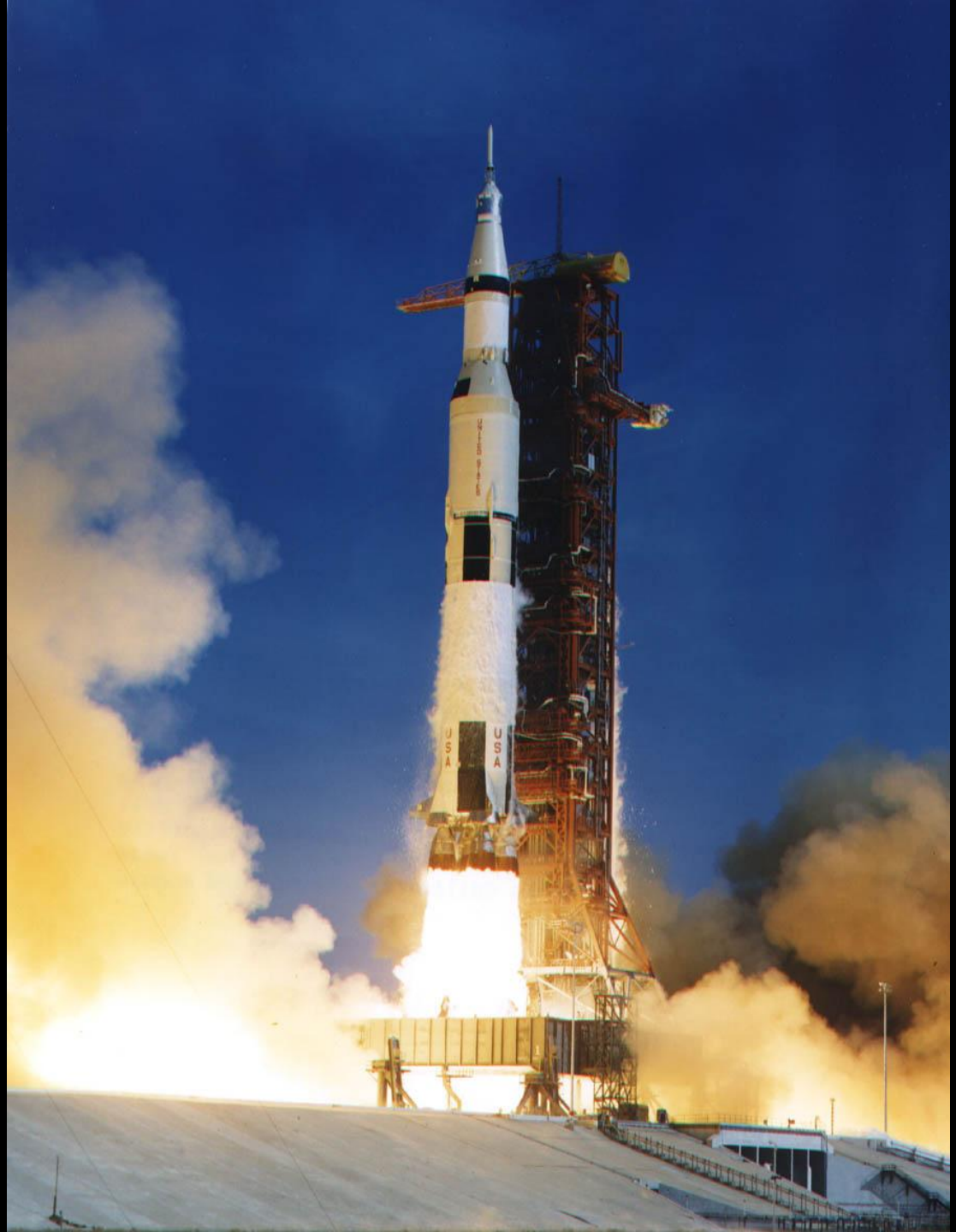


Apollo 11

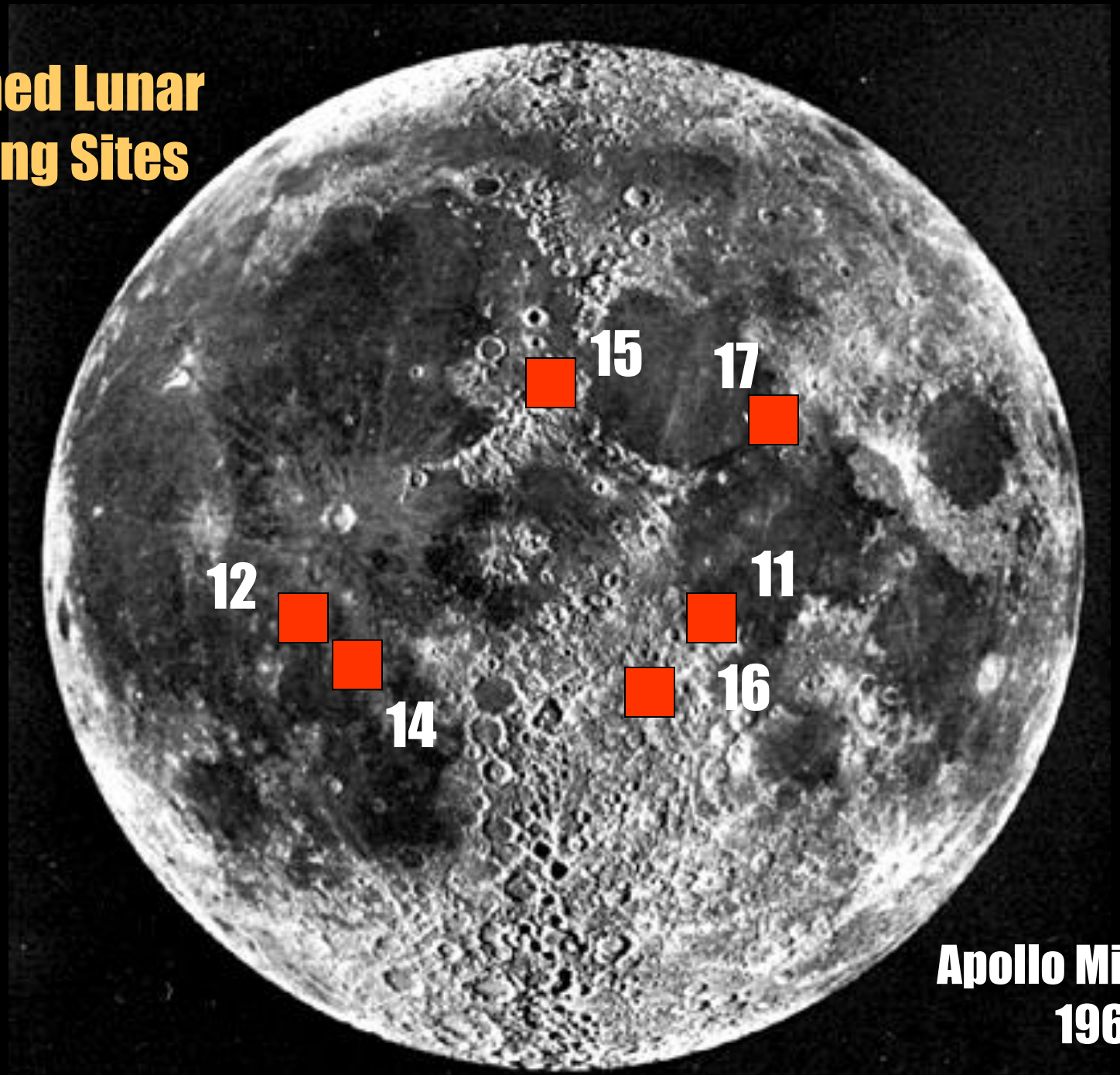
16 Jul 1969

Armstrong
Collins
Aldrin

Apollo 11

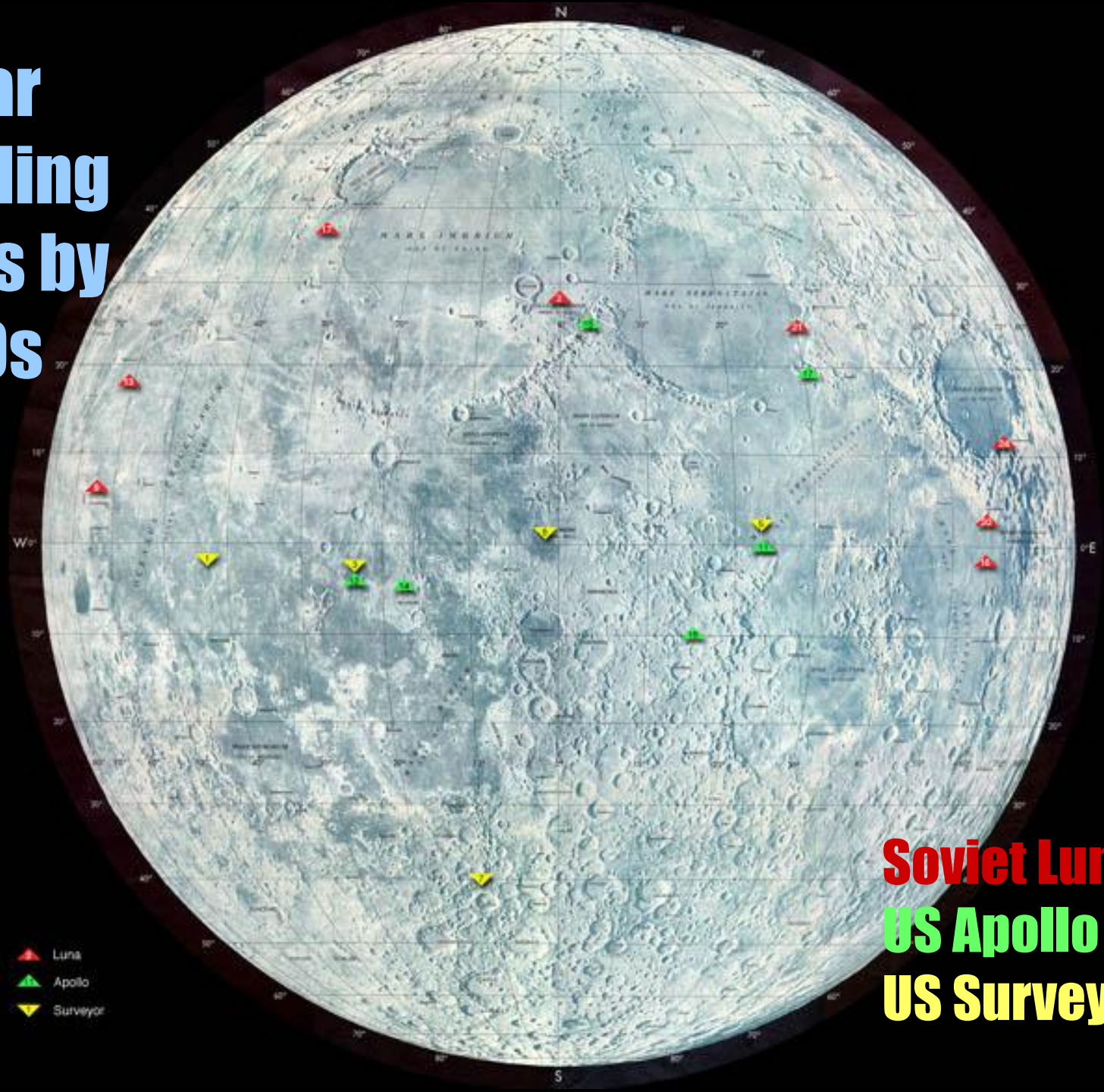


Manned Lunar Landing Sites



Apollo Missions
1969-1972

Lunar Landing Sites by 1970s



Soviet Luna (8)

US Apollo (6)

US Surveyor (5)

Artemis Missions 2022-2029

√ Artemis I – 2022

√ Artemis II – 2026 *

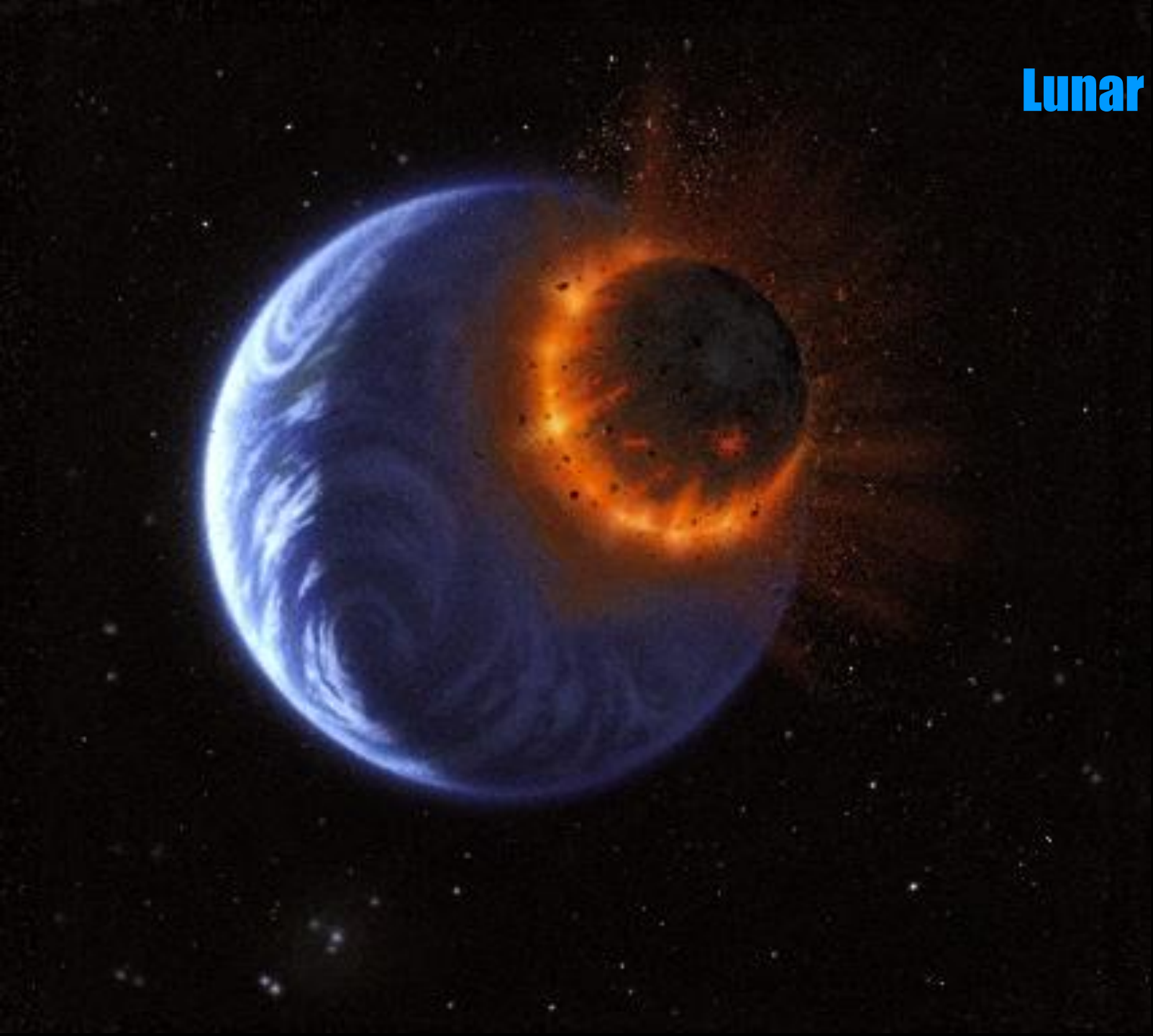
Artemis III – 2027

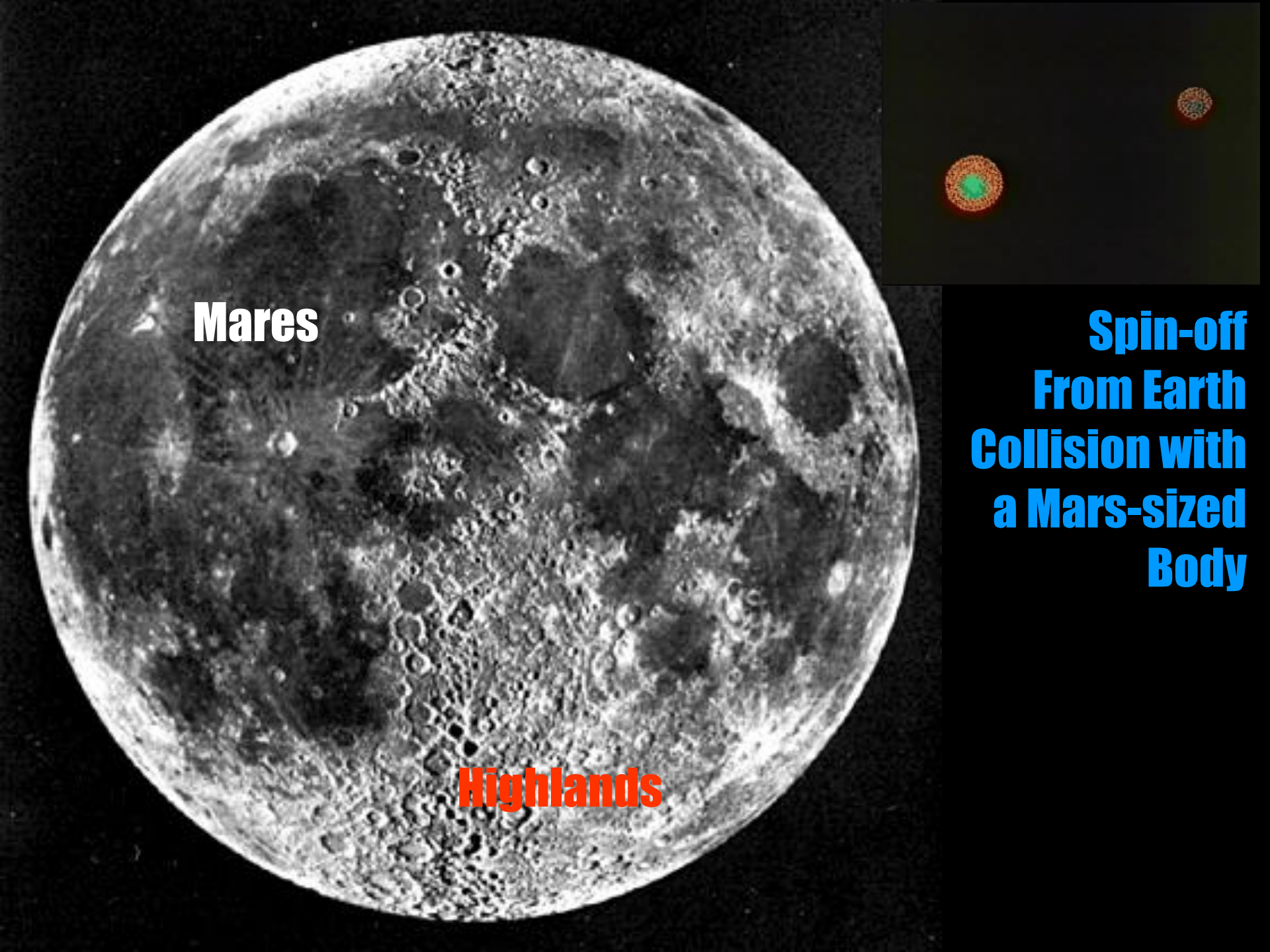
Artemis IV – 2028*

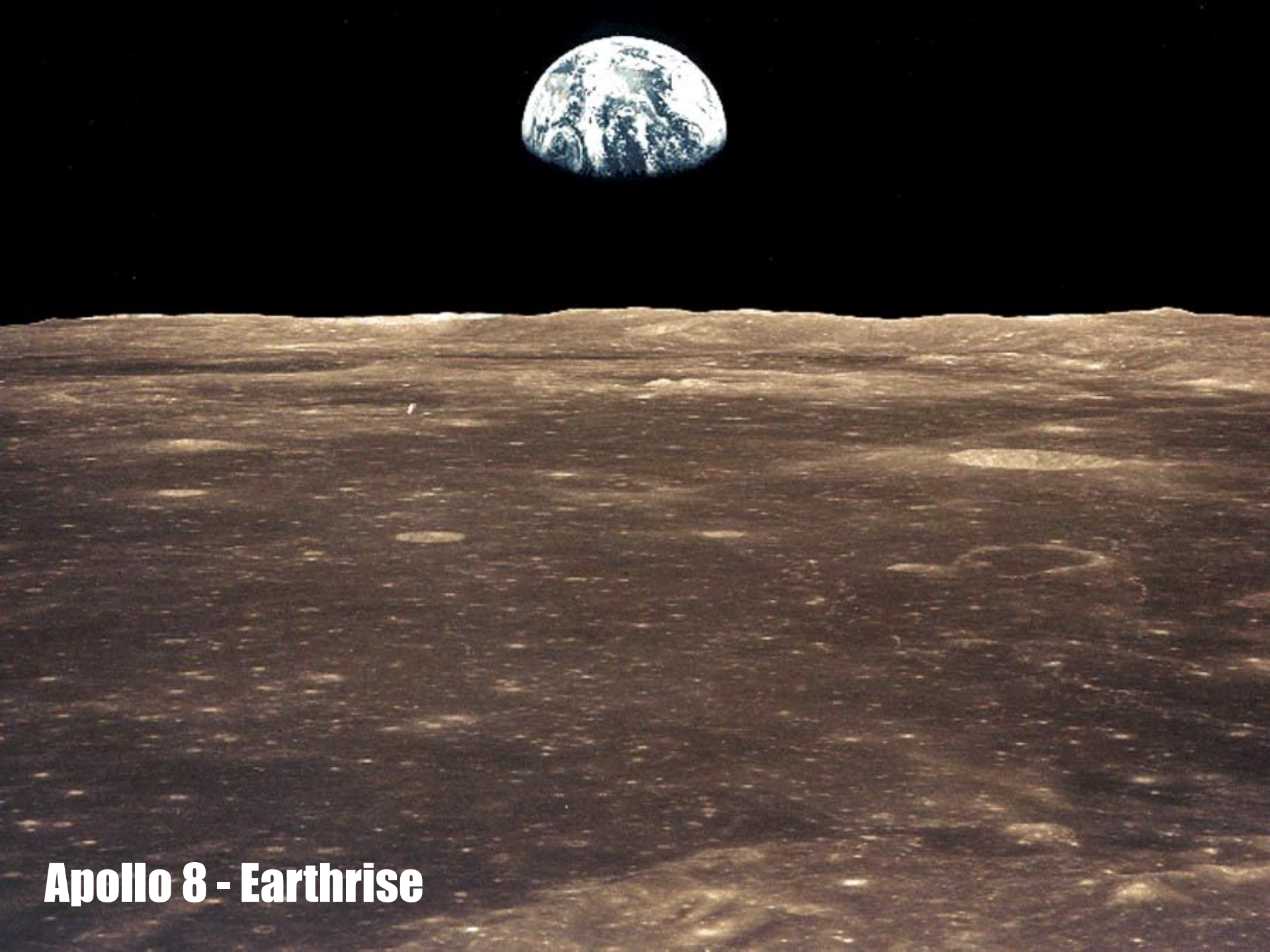
Artemis V – 2029 *

* = Manned

Lunar Origin




Mares
Highlands
Spin-off
From Earth
Collision with
a Mars-sized
Body


Apollo 8 - Earthrise

Time

Formation of Imbrian and Orientale Basins = 3.8 Ga

NECTARIAN PERIOD ========== 3.95 Ga

Formation of 10-12 huge multi-ringed basins

PRE-NECTARIAN PERIOD ========== 4.05 Ga

Intense cratering with formation of ~30 multi-ringed basins including Oceanus Procellarum and south polar Aitken basins

Anorthositic lunar crust forms during crystallization of magma ocean – Rockbergs of felsic crust!

Moon forms by Mars-sized impact with proto-Earth, hurling pre-lunar materials into near-Earth orbit Where they collect and form molten proto-moon

COPERNICAN PERIOD ========== **0 Ma**

Formation of crater Tycho ~ 108 Ma

Formation of crater Copernicus ~ 800-900 Ma

ERATOSTHENIAN PERIOD ========== **1.1 Ga**

Limited basaltic volcanism (~2.1 Ga)

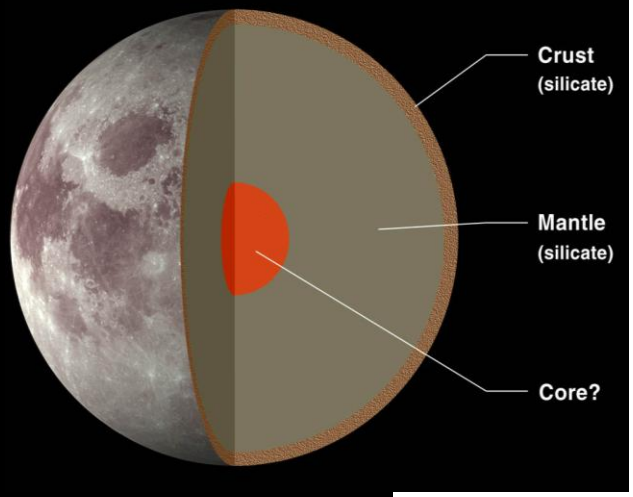
Decreased cratering (<late Imbrian rate)

Basaltic lavas flow into Oceanus Procellarum and Imbrium Basin (~3.2 Ga)

IMBRIAN PERIOD ========== **3.2 Ga**

Flooding of multi-ringed craters eventually covering 17% of lunar near side

Impact cratering slows to 1.5% of Nectarian rates



Earth

Deep moon quakes

Crust

Dense layer

?

Mantle

Partly molten zone?

700 km

1100 km

Core (?)

1740 km

?

Mare (basalt lava)

Shallow moon quakes

Mass = 0.07349 x 10^{24} kg; 0.0123 M_e
Radius = 1737 km; 0.2727 R_e
Density (ρ) = 3.350 g/cm^3 ; 0.607 ρ_e
Rotation = 27.322 Days
Revolution = 27.3217 Days
Distance to Sun = 1 AU

Age = 4.6 Ga

Atmos. = ^{4}He, ^{20}Ne, H_2, ^{40}Ar, ^{22}Ne, ^{36}Ar, CH_4, NH_3, CO_2

Traces of Ionized O, Al, Si, P, Na, Mg

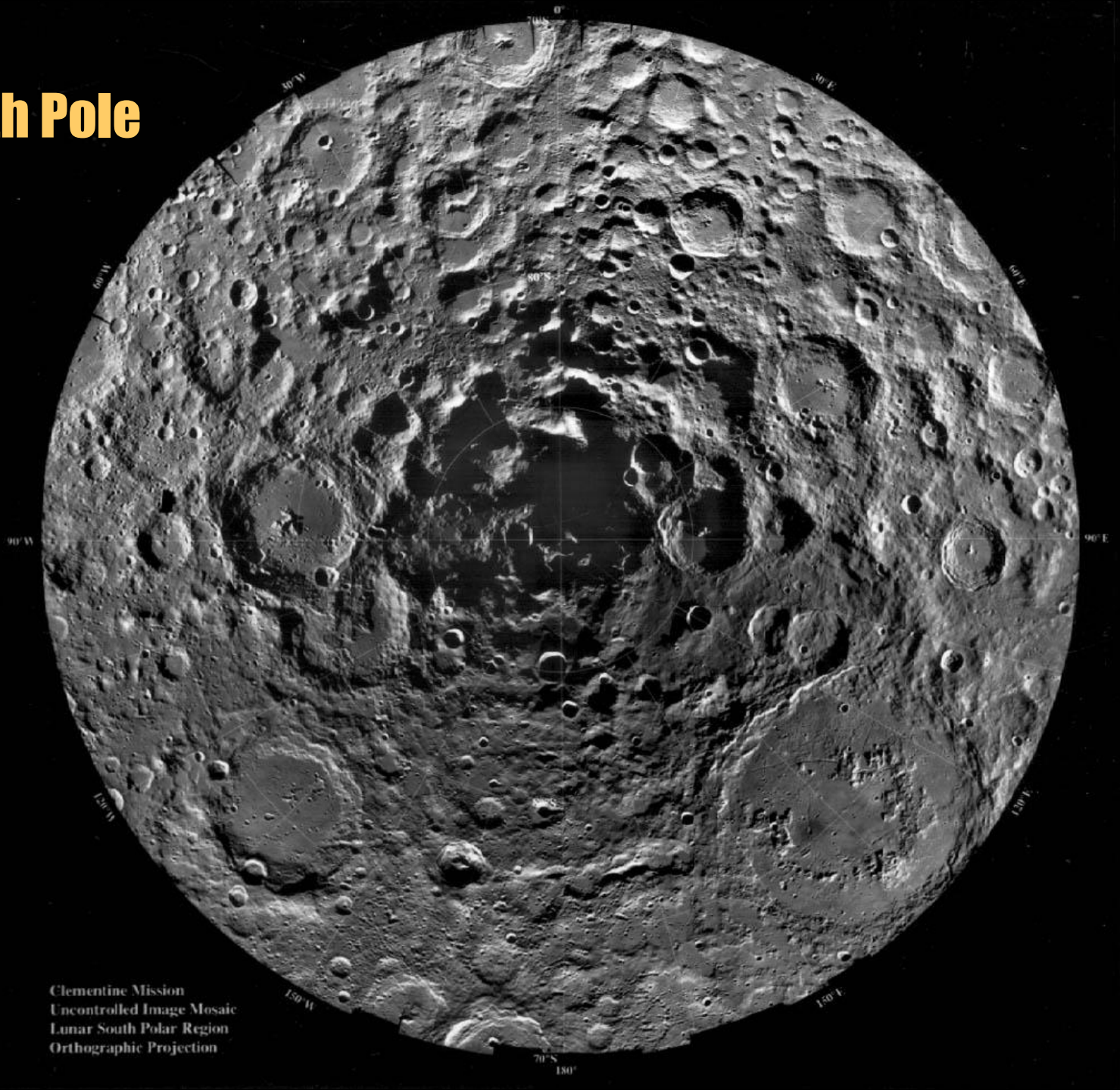
Surface Pressure = 3×10^{-15} bar

Surface Temperature = 100°K – 400°K

Magnetic Field = ~ 0.00 B_e

Gravity Field = 0.165 G_e

South Pole

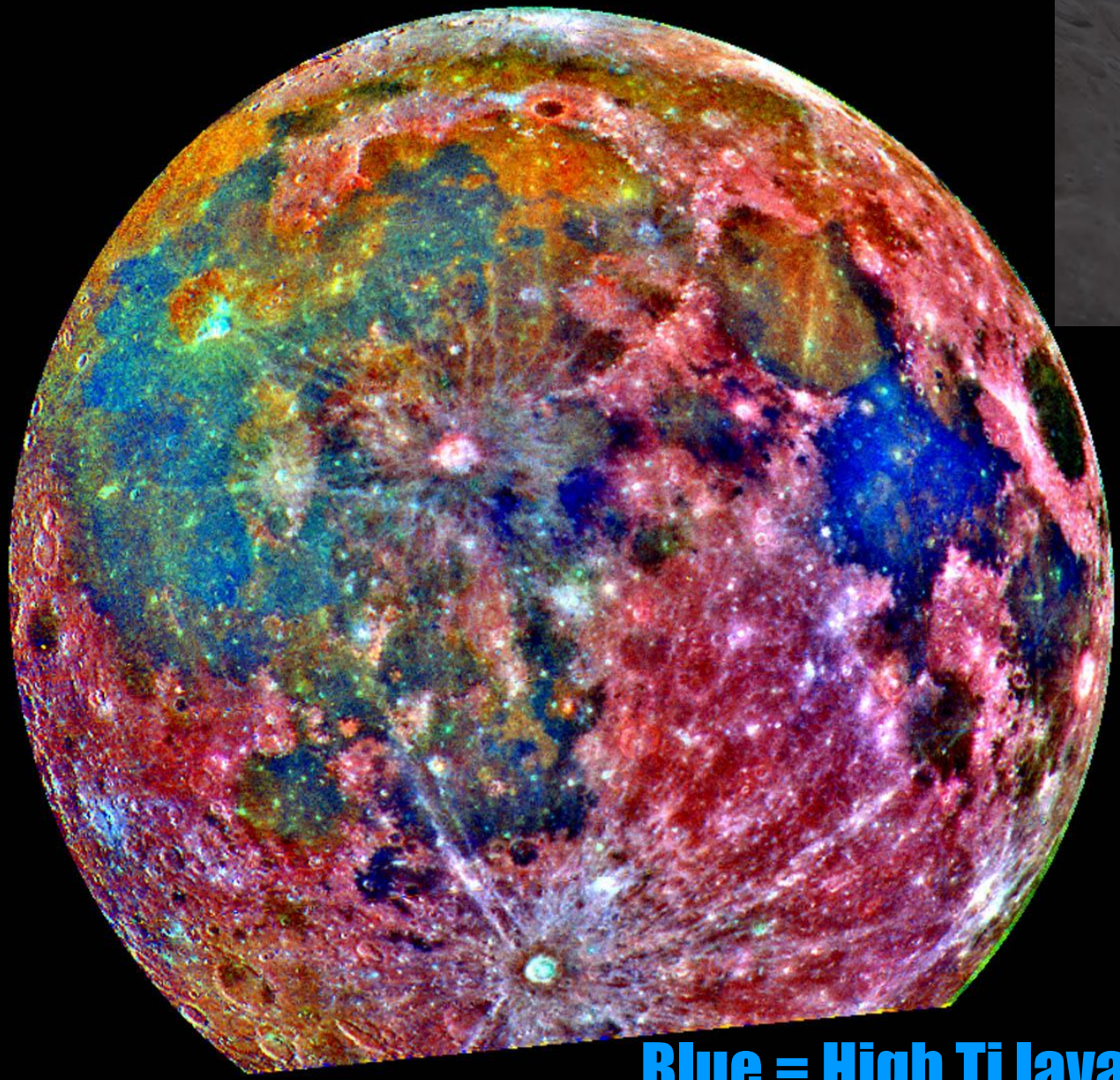


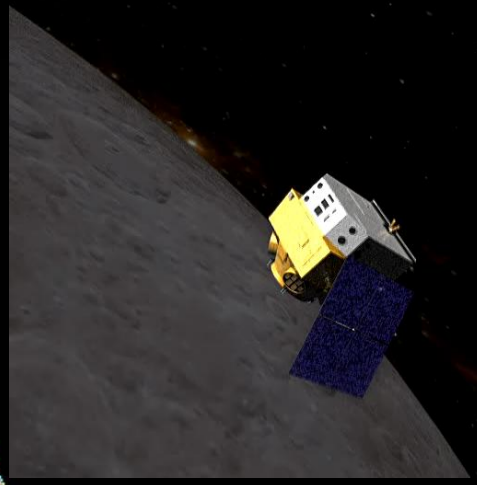
Clementine Mission
Uncontrolled Image Mosaic
Lunar South Polar Region
Orthographic Projection

Lunar Farside

Crater Copernicus
~800-900 Ma

Crater Copernicus
~800-900 Ma

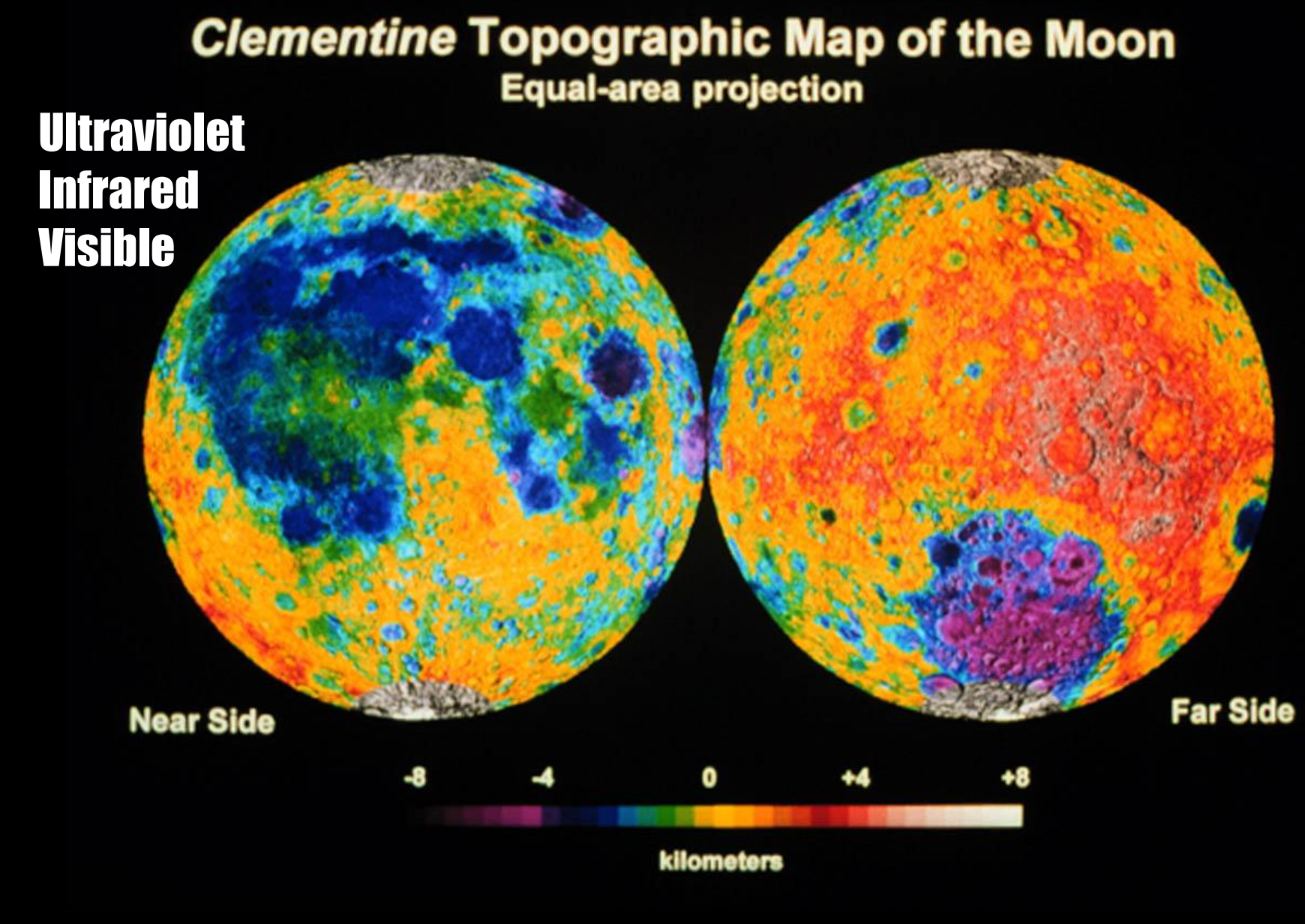


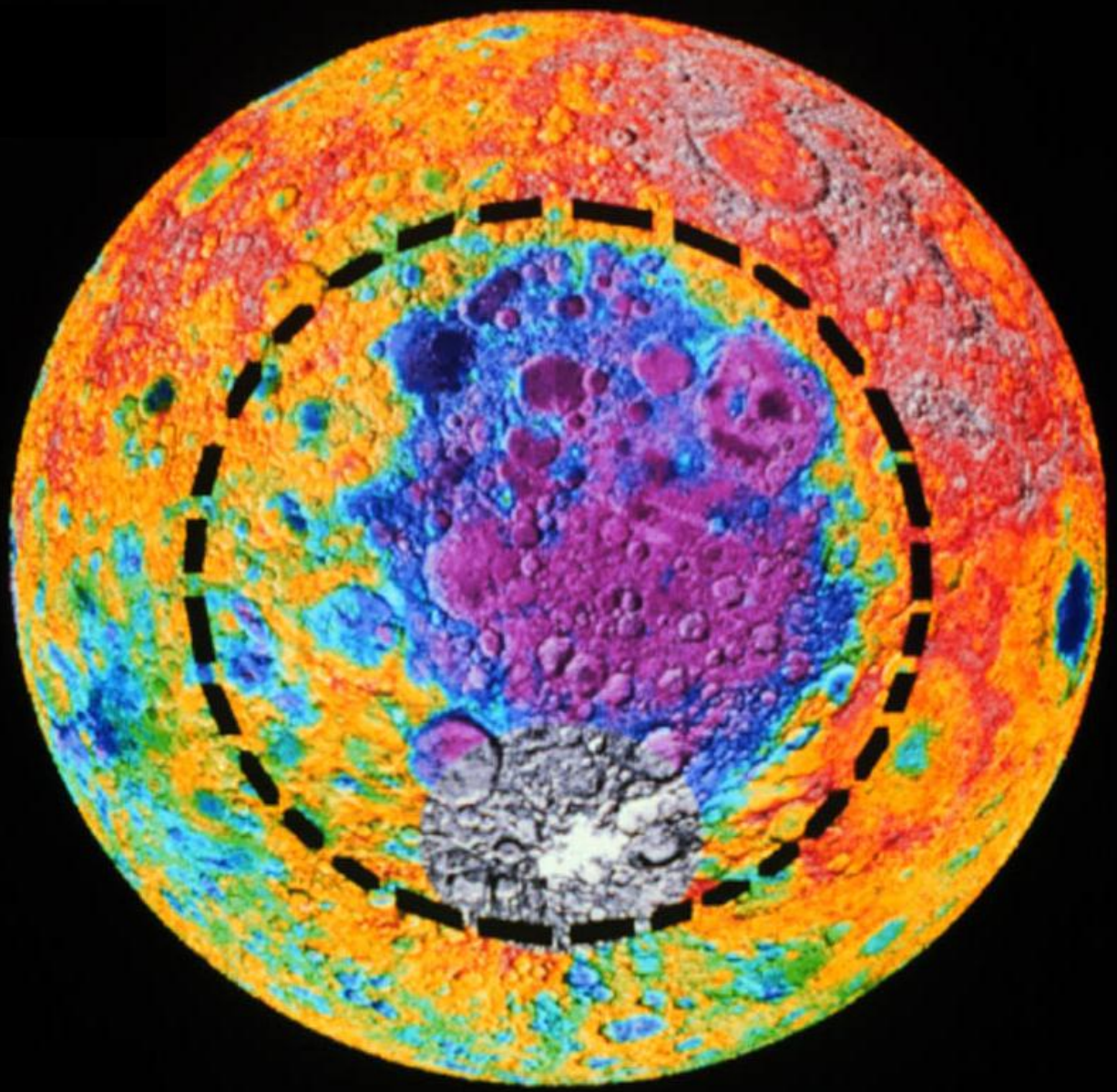


Galileo fly-bys in 1990 and 1992 while gaining speed in earth orbit to reach Jupiter by gravity assist

Blue = High Ti lavas; Red = Highlands

Clementine Lunar Recon Orbiter 1994





Aitken Basin
2600 km across
12 km deep

Biggest Impact Feature in Solar System

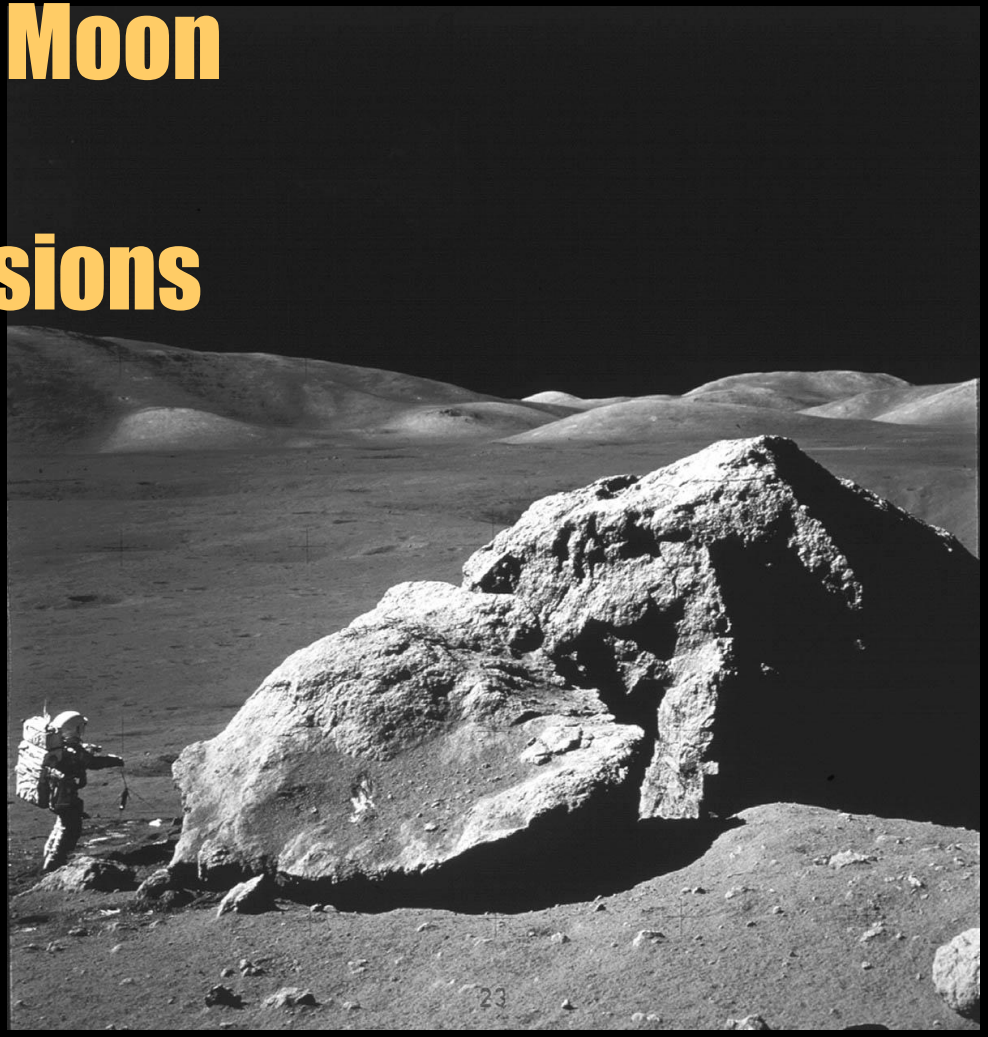
Water Ice in Spectral Surveys Verified by Lunar Prospector in 1998

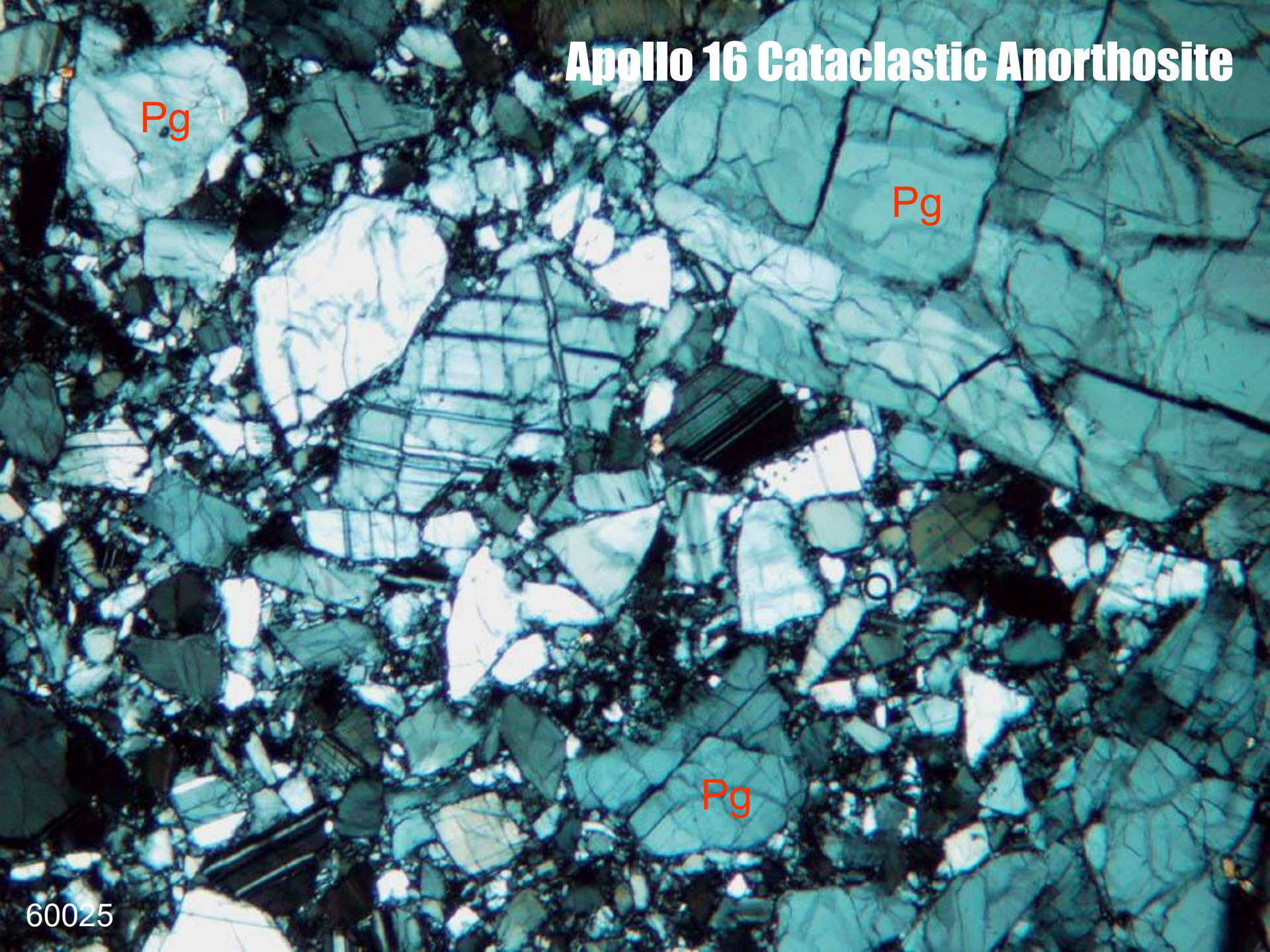

The Petrographic Microscope
The Field Geologist's Second Best Friend

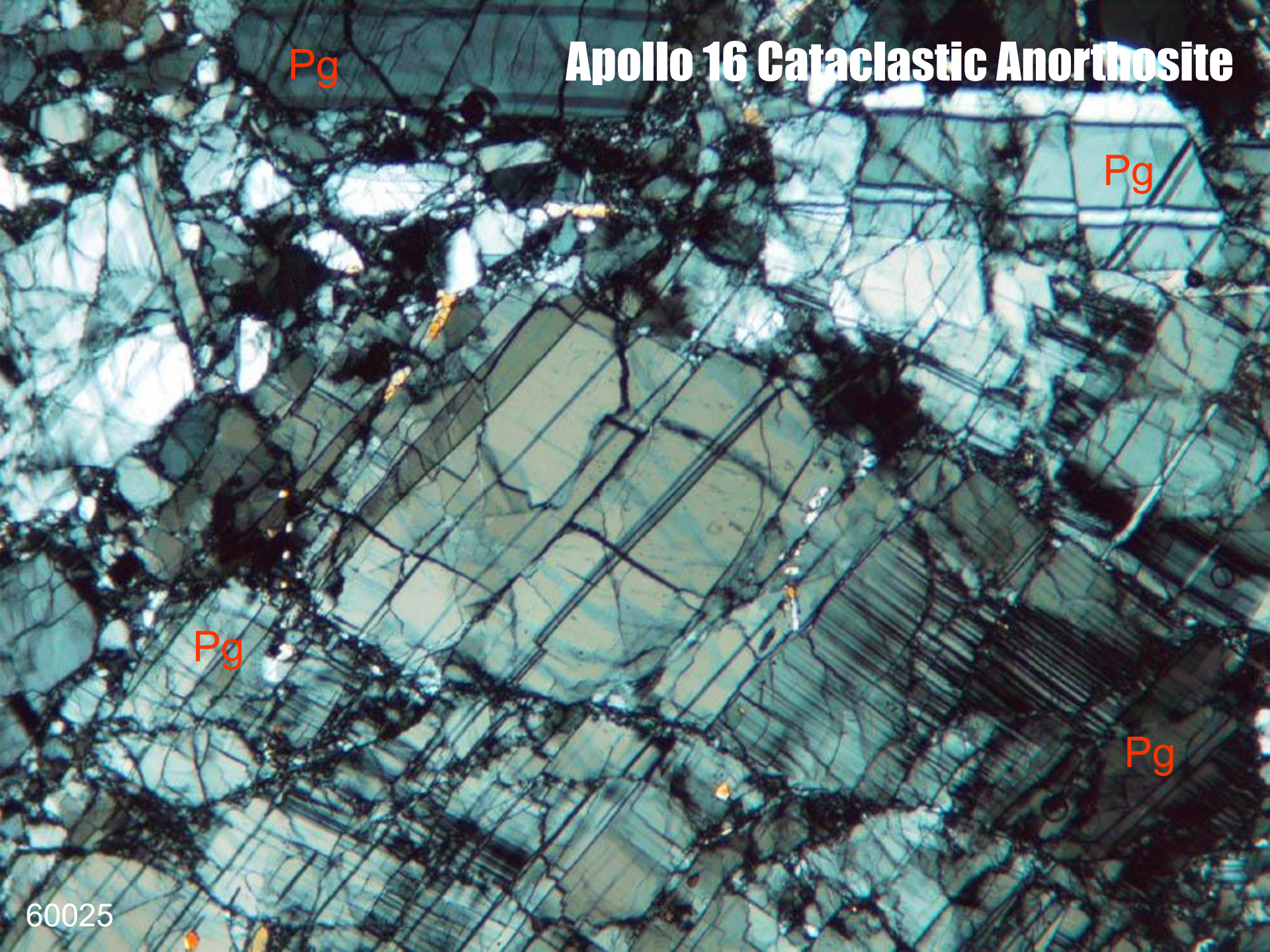
Plutonic Anorthositic Rocks

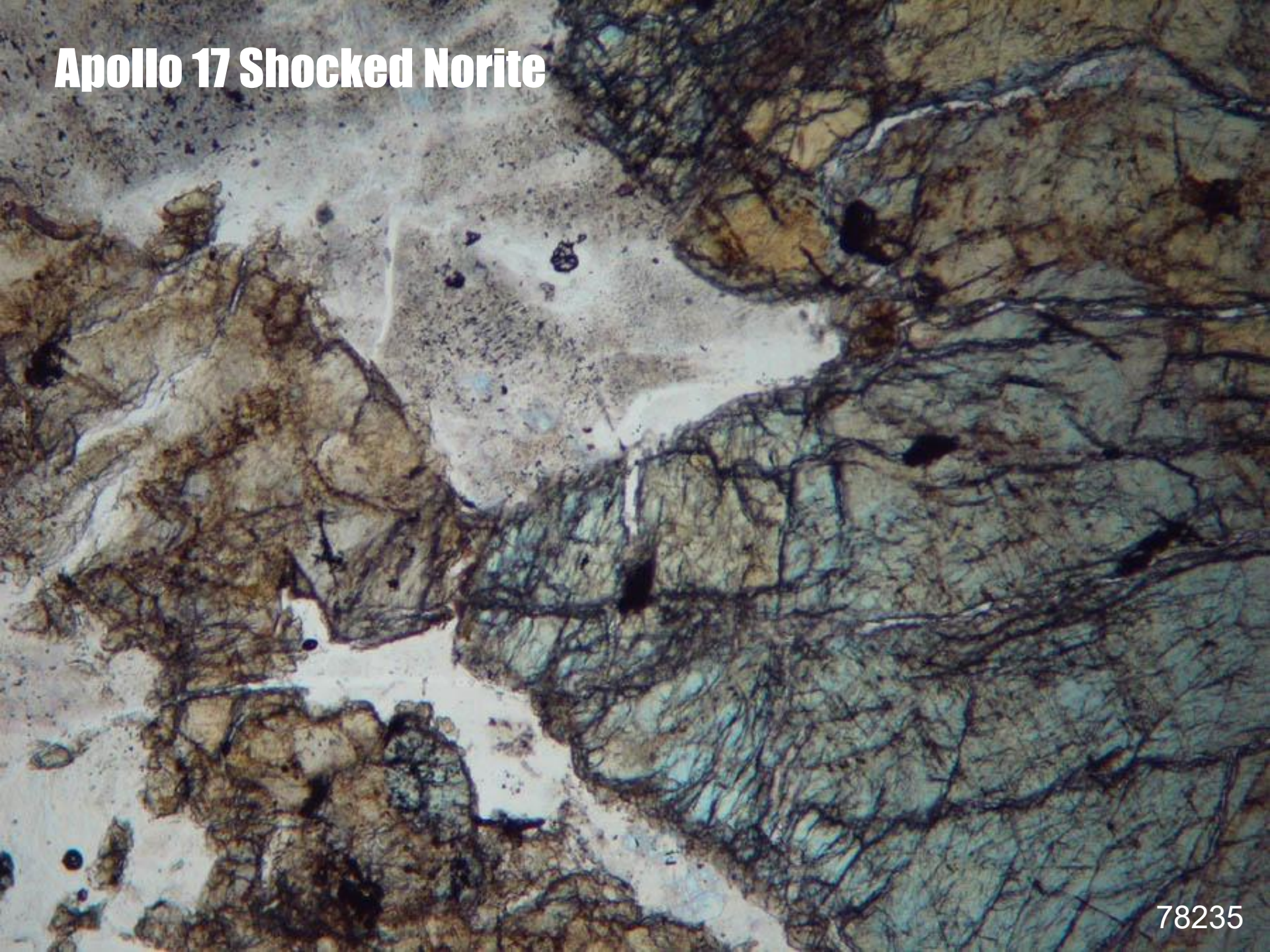
Oldest Rocks on the Moon

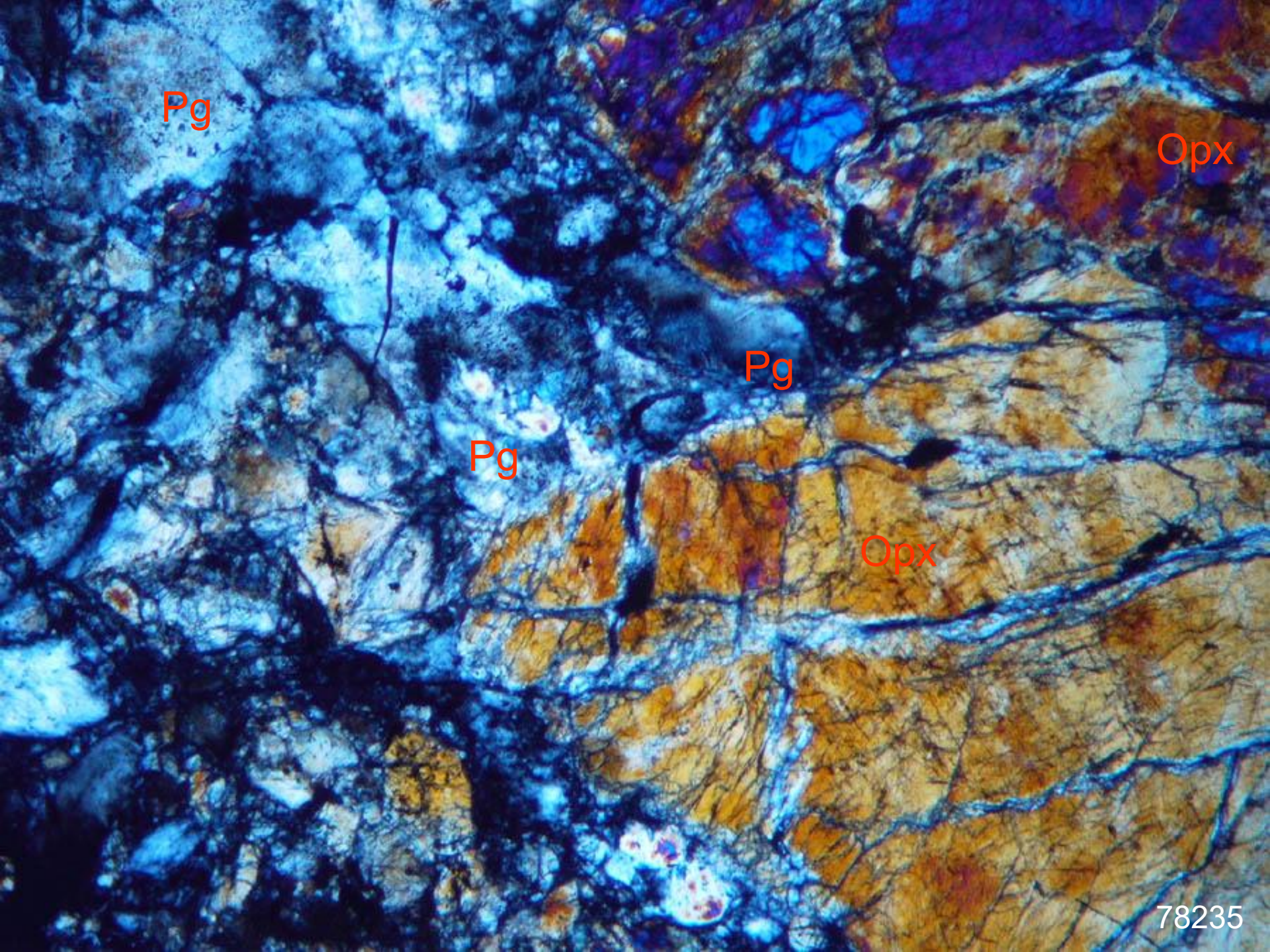
Apollo 16 and 17 Missions

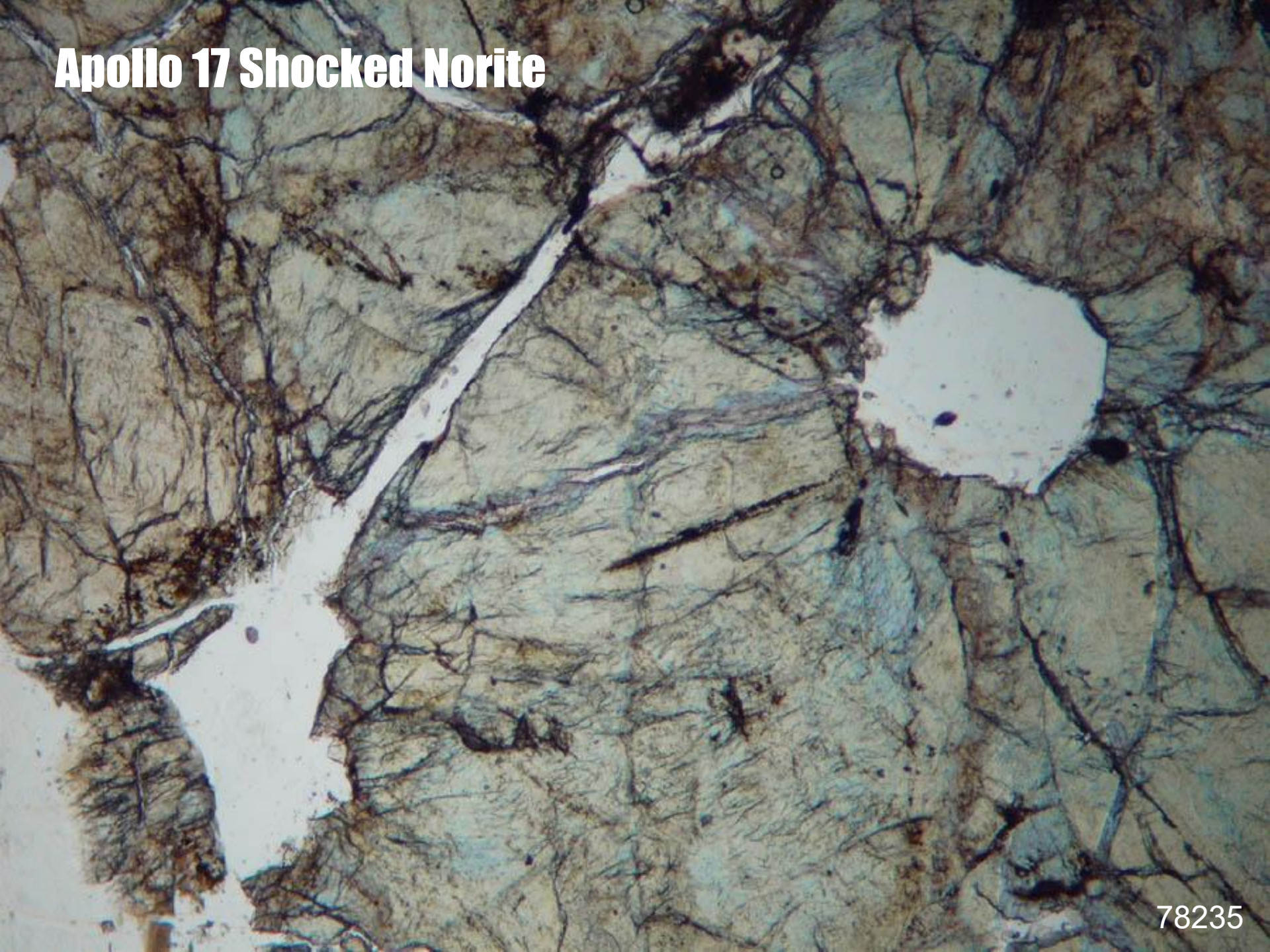



Apollo 16 Cataclastic Anorthosite
Pg
Pg
Pg
60025


Apollo 16 Cataclastic Anorthosite
Pg
Pg
Pg
Pg
60025


Apollo 17 Shocked Norite
78235


Pg
Opx
Pg
Pg
Opx
78235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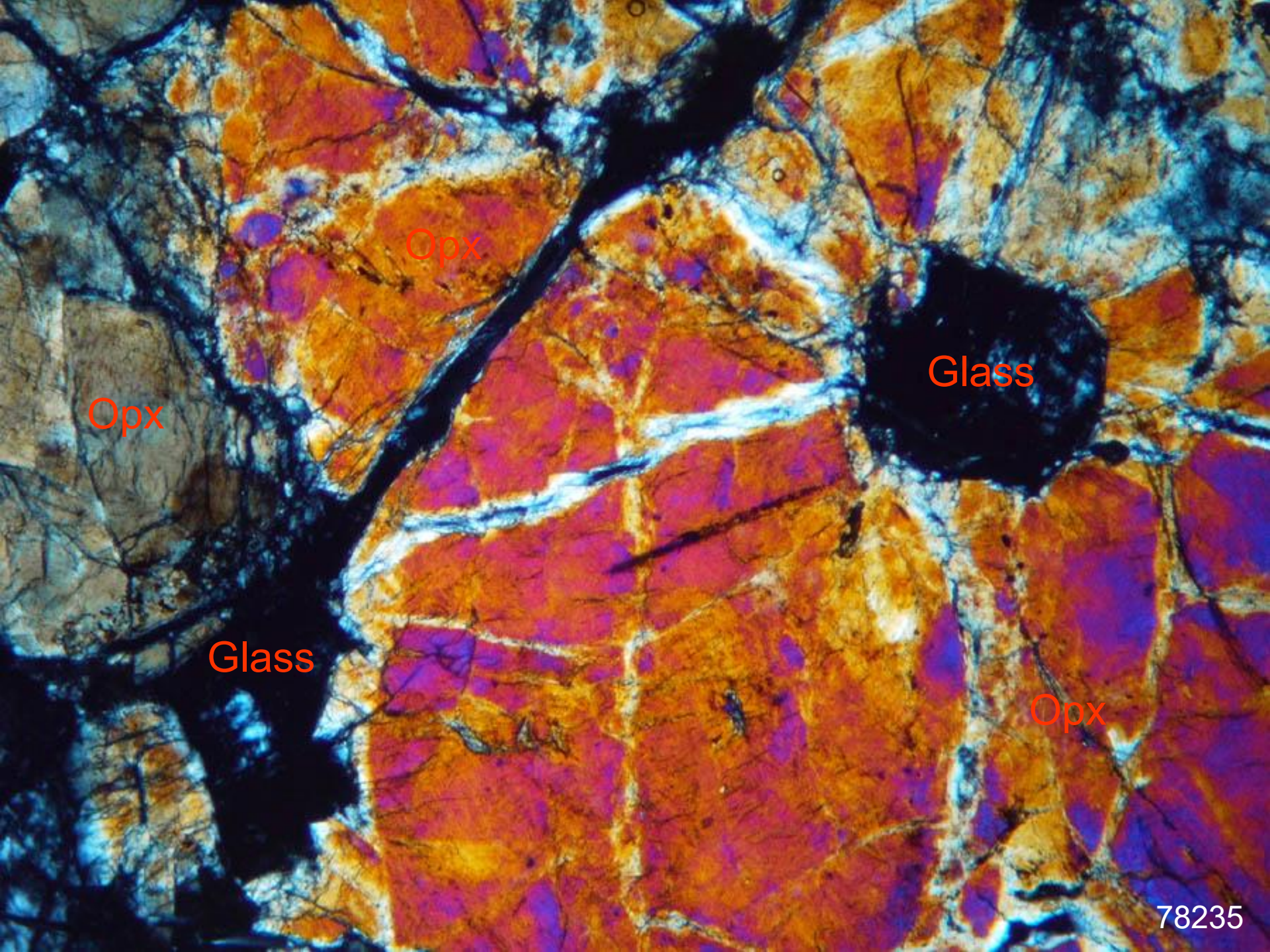
Opx
Glass
Opx
Glass
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78235

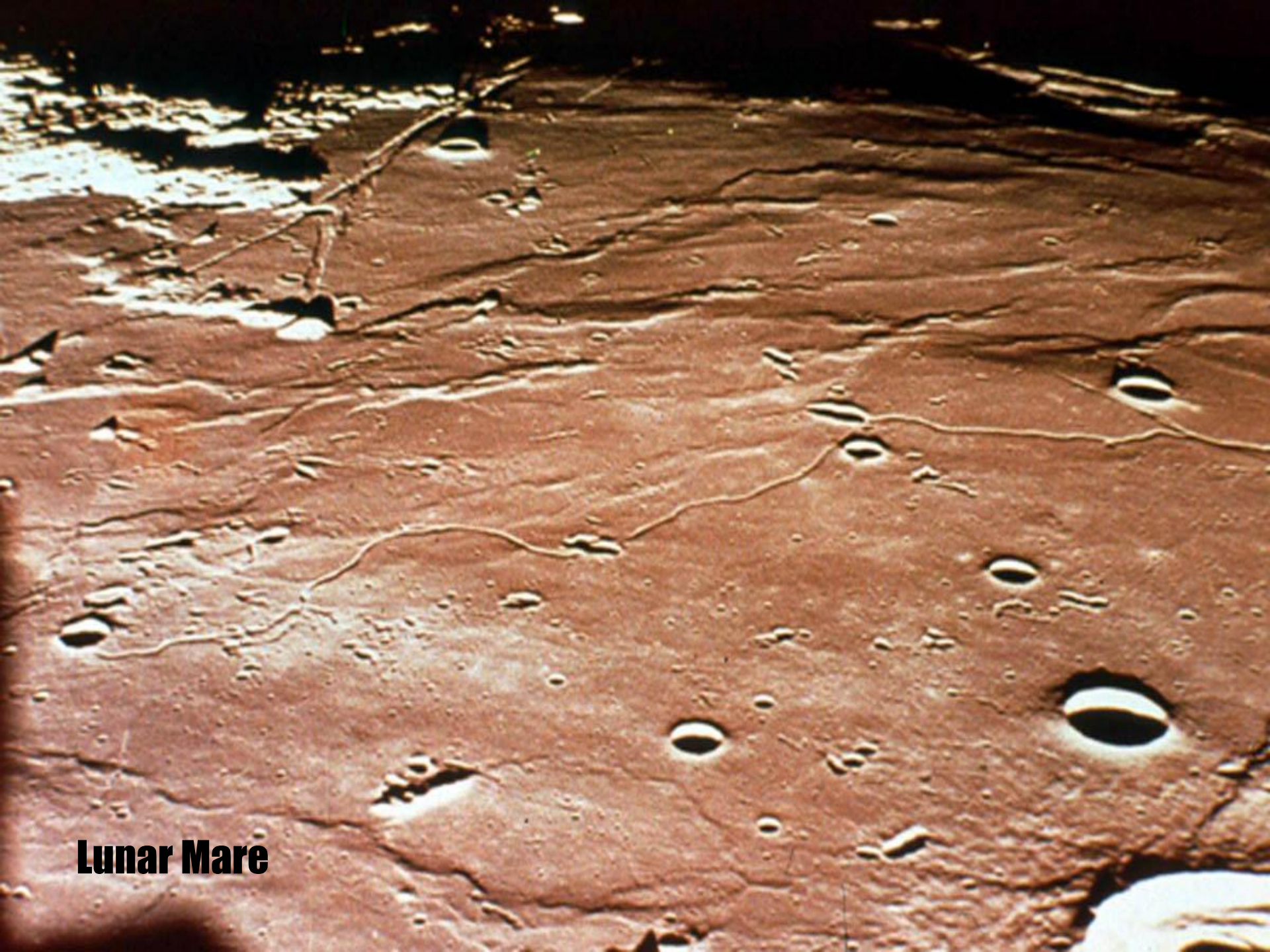
Mare Basalts

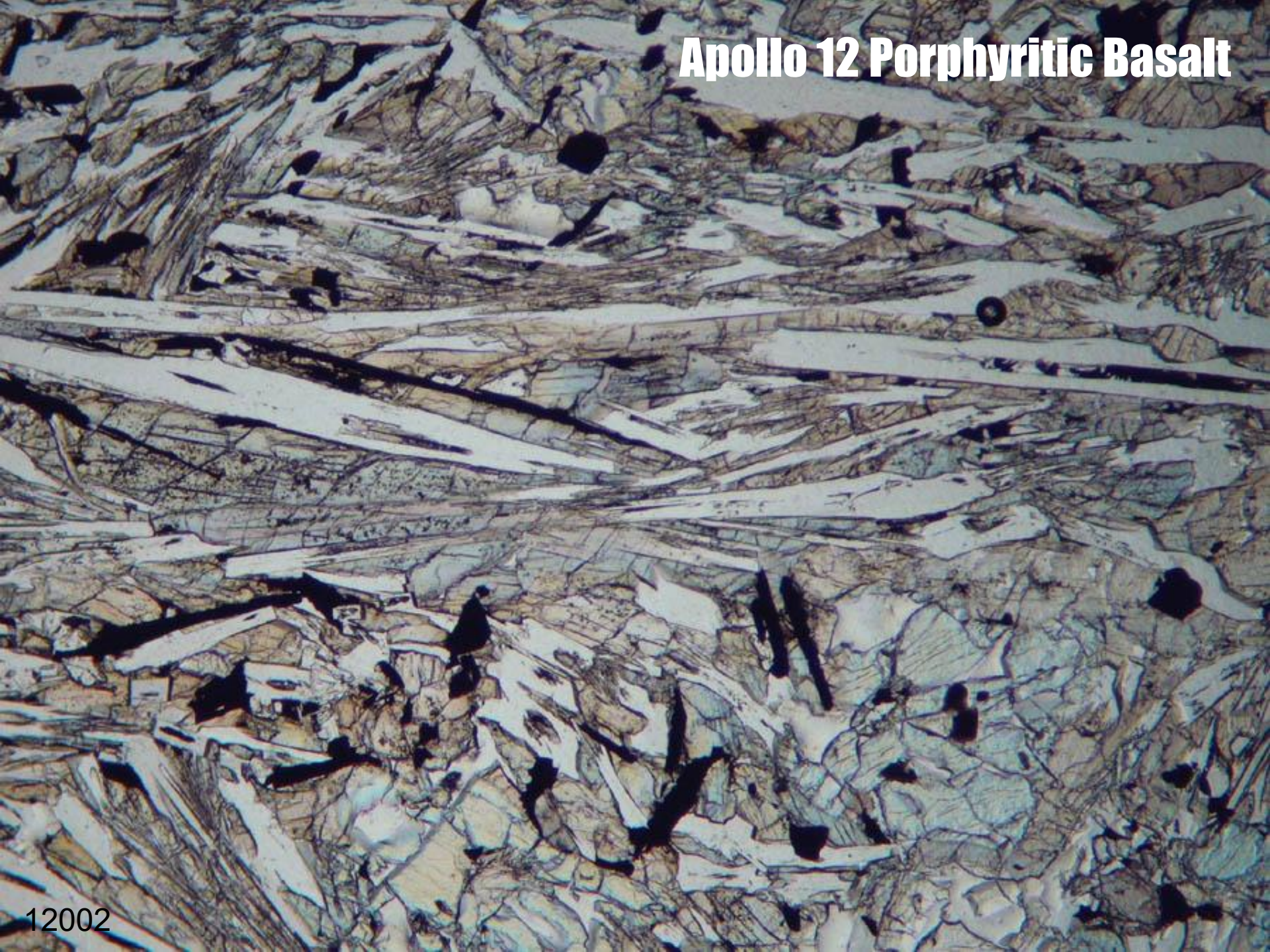
Porphyritic Basalt - Apollo 12

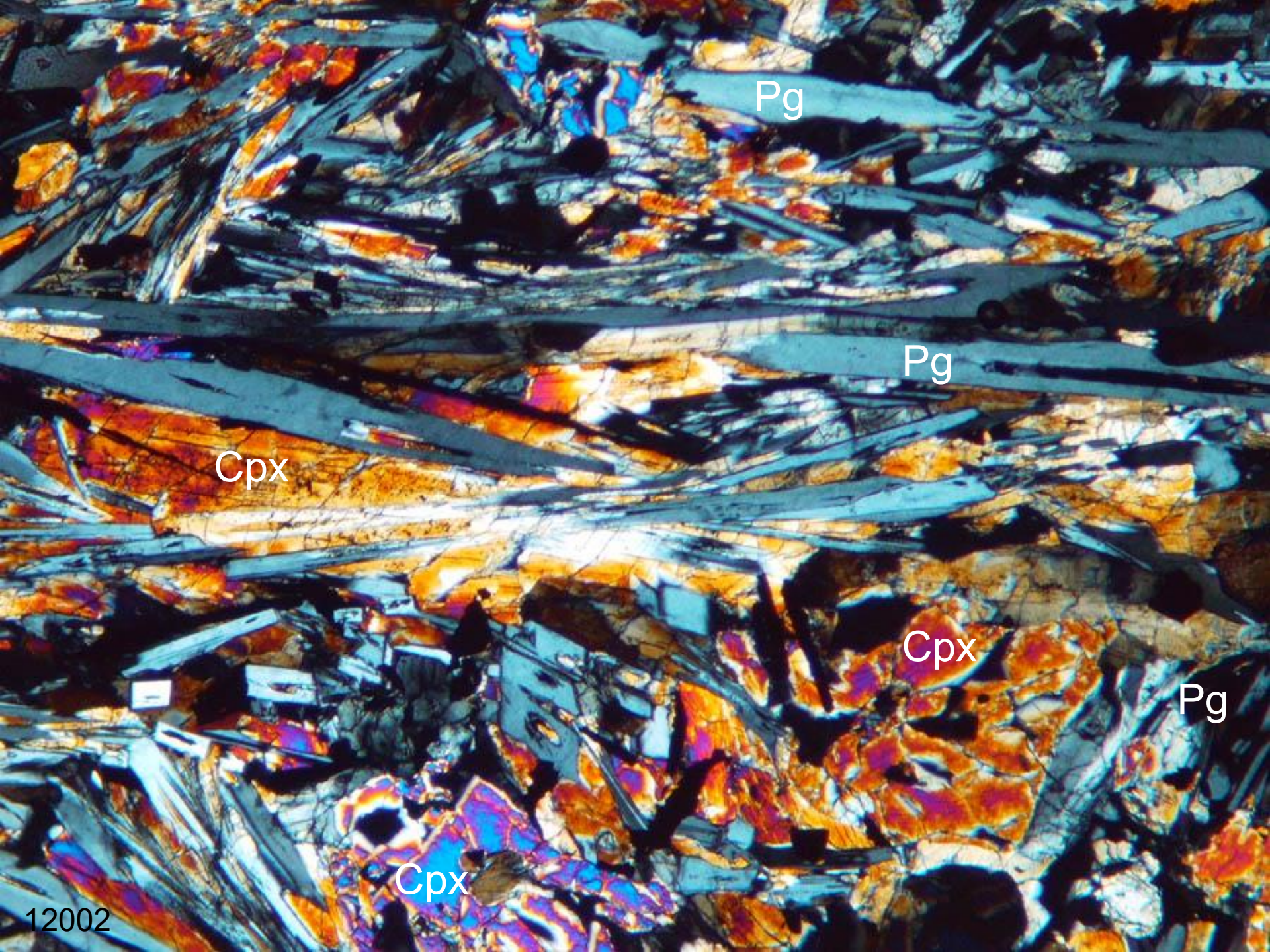
Olivine Basalt - Apollo 12

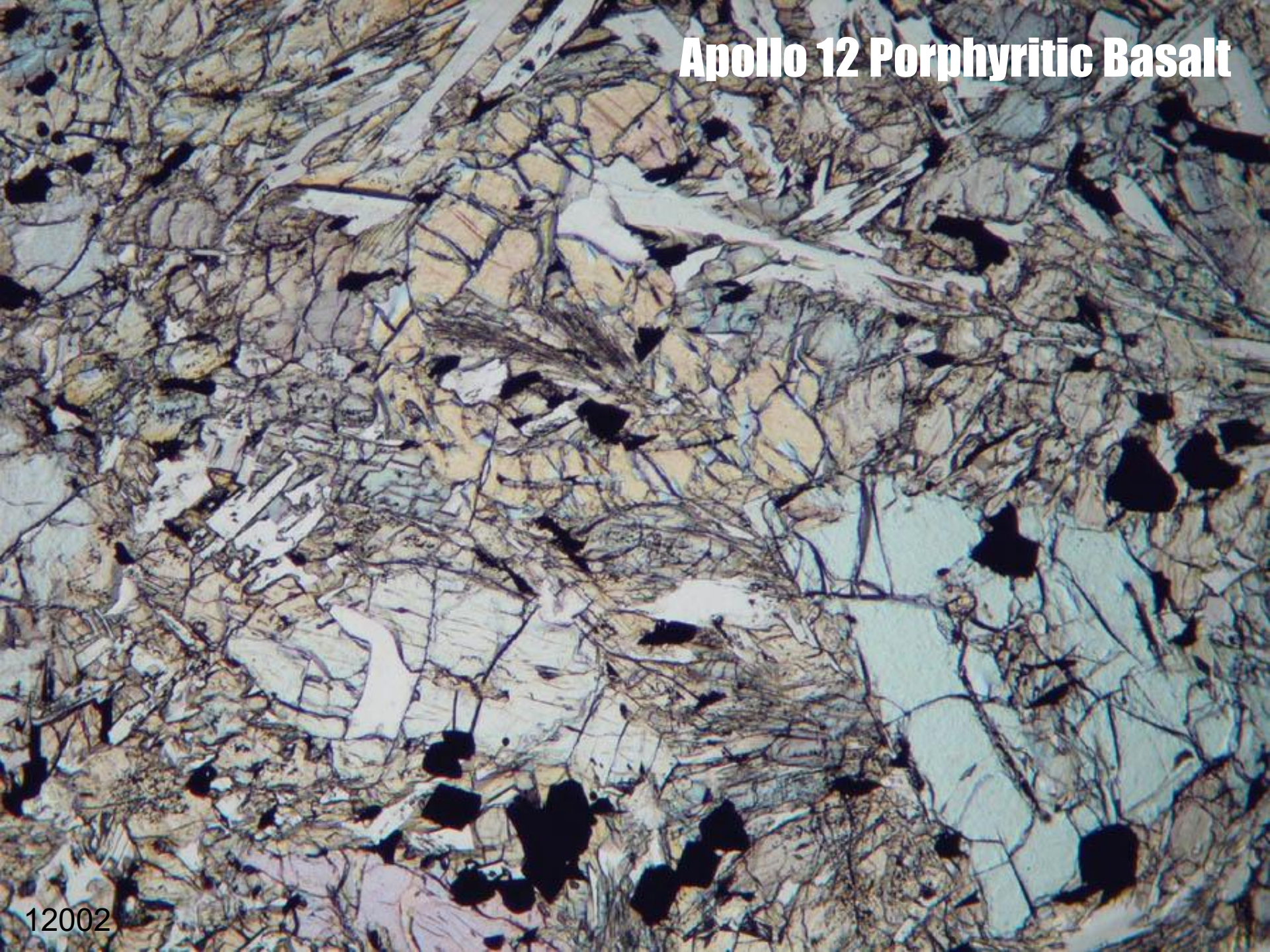
High-Ti Basalt – Apollo 17

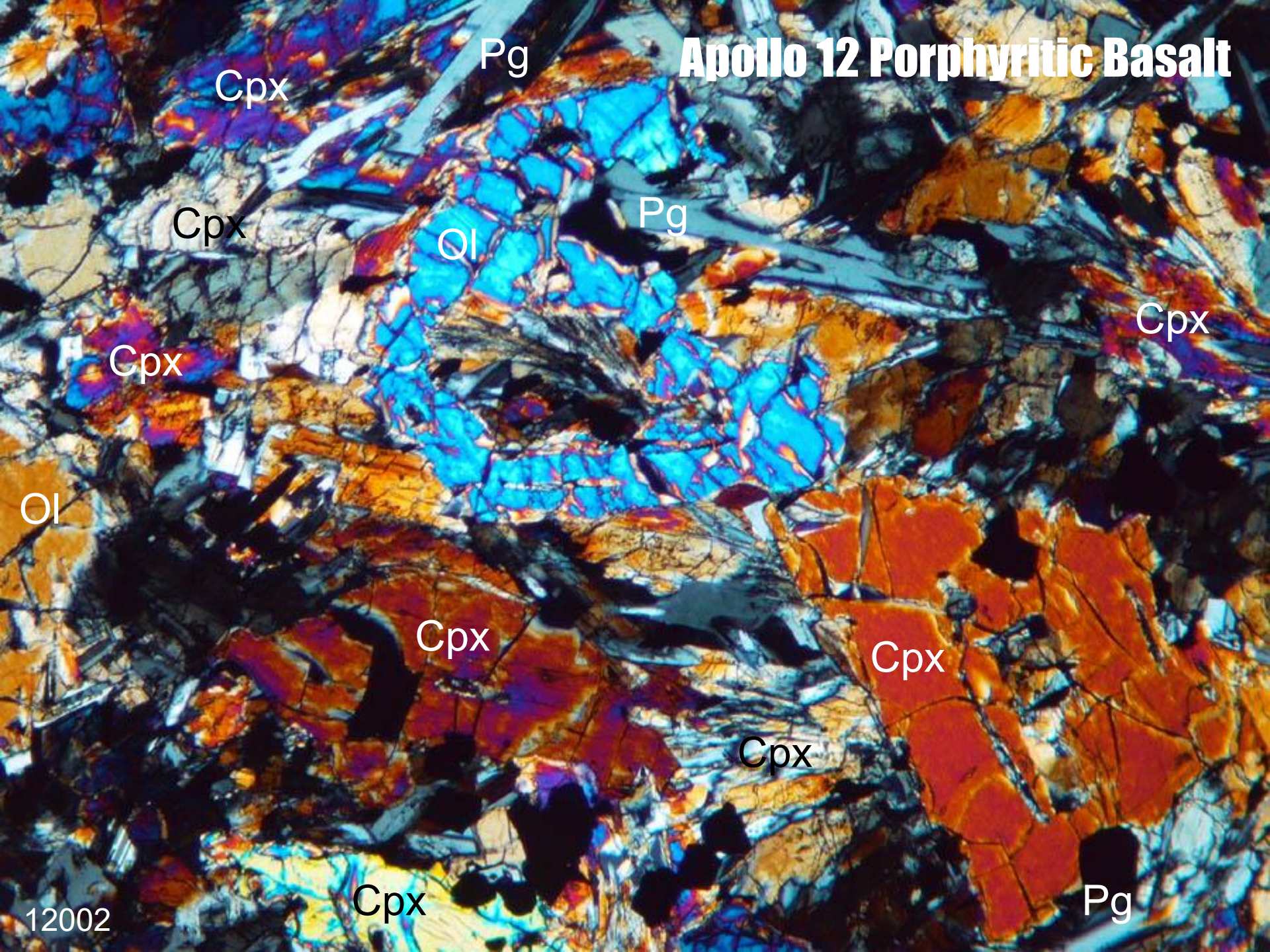
Volcanic Glass – Apollo 17

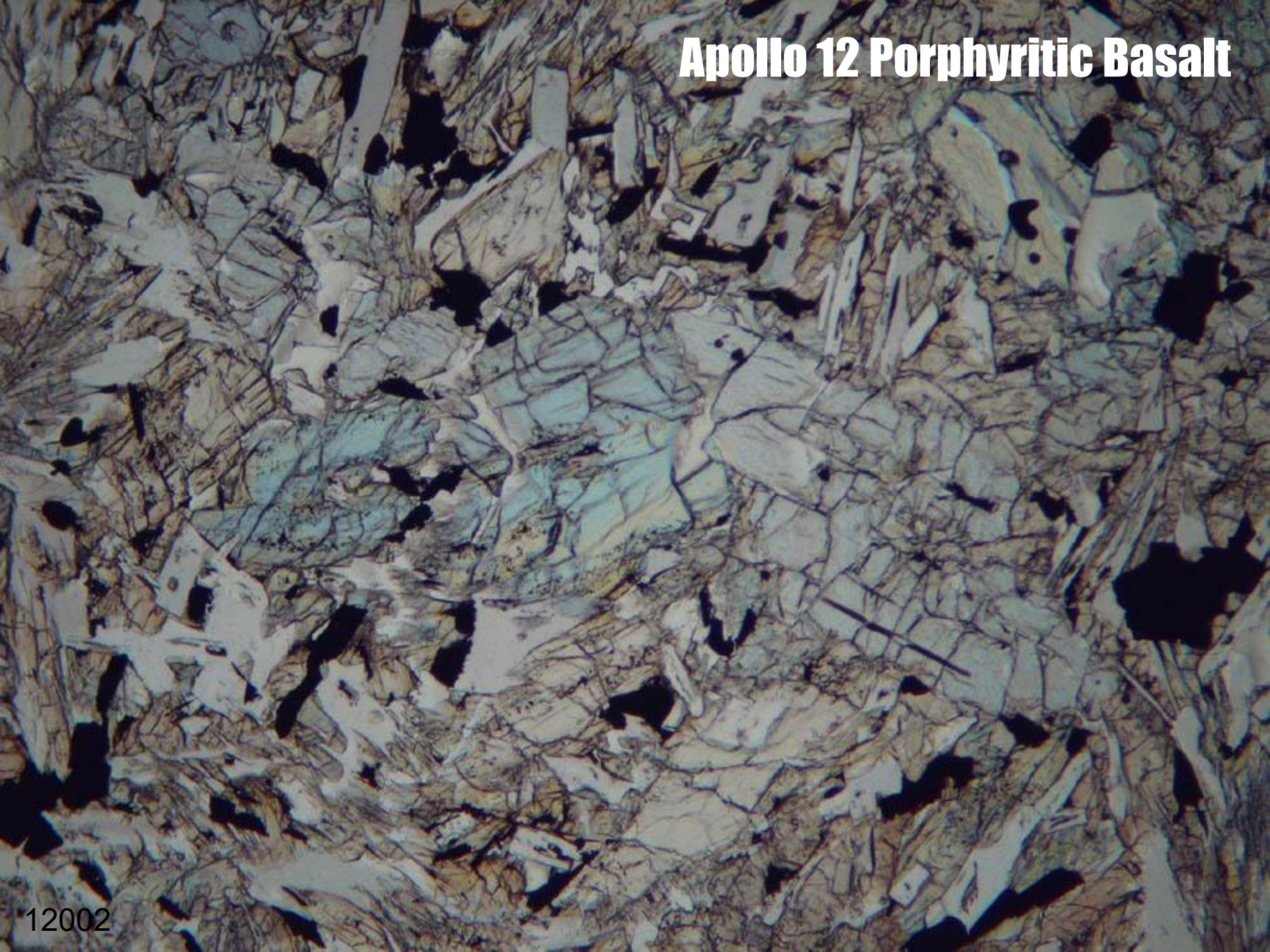

Lunar Mare


Apollo 12 Porphyritic Basalt
12002


Pg
Pg
Cpx
Cpx
Pg
Cpx
12002


Apollo 12 Porphyritic Basalt
12002


Apollo 12 Porphyritic Basalt
Pg
Cpx
Cpx
Ol
Pg
Cpx
Cpx
Ol
Cpx
Cpx
Cpx
Cpx
Pg
12002


Apollo 12 Porphyritic Basalt
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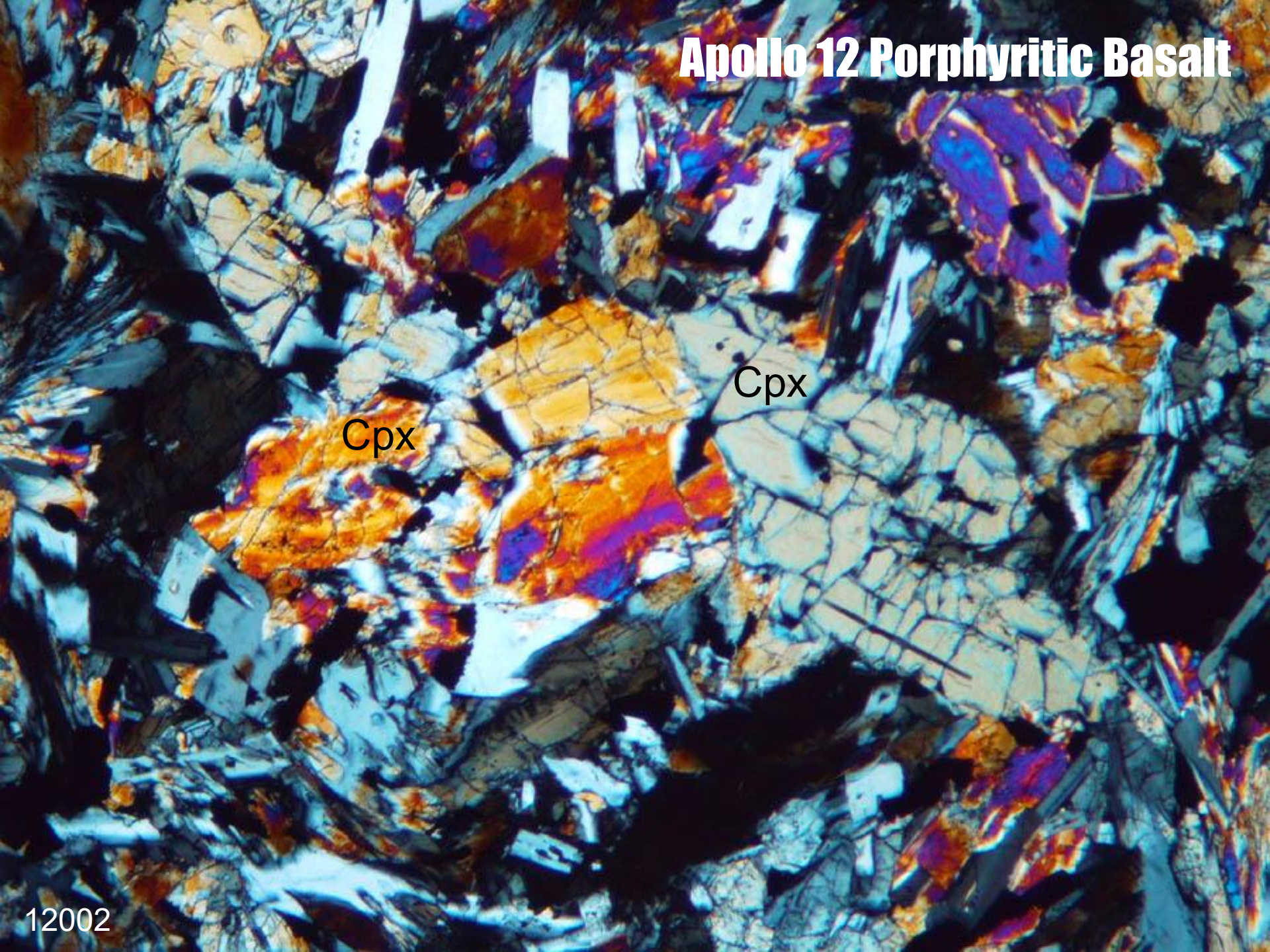
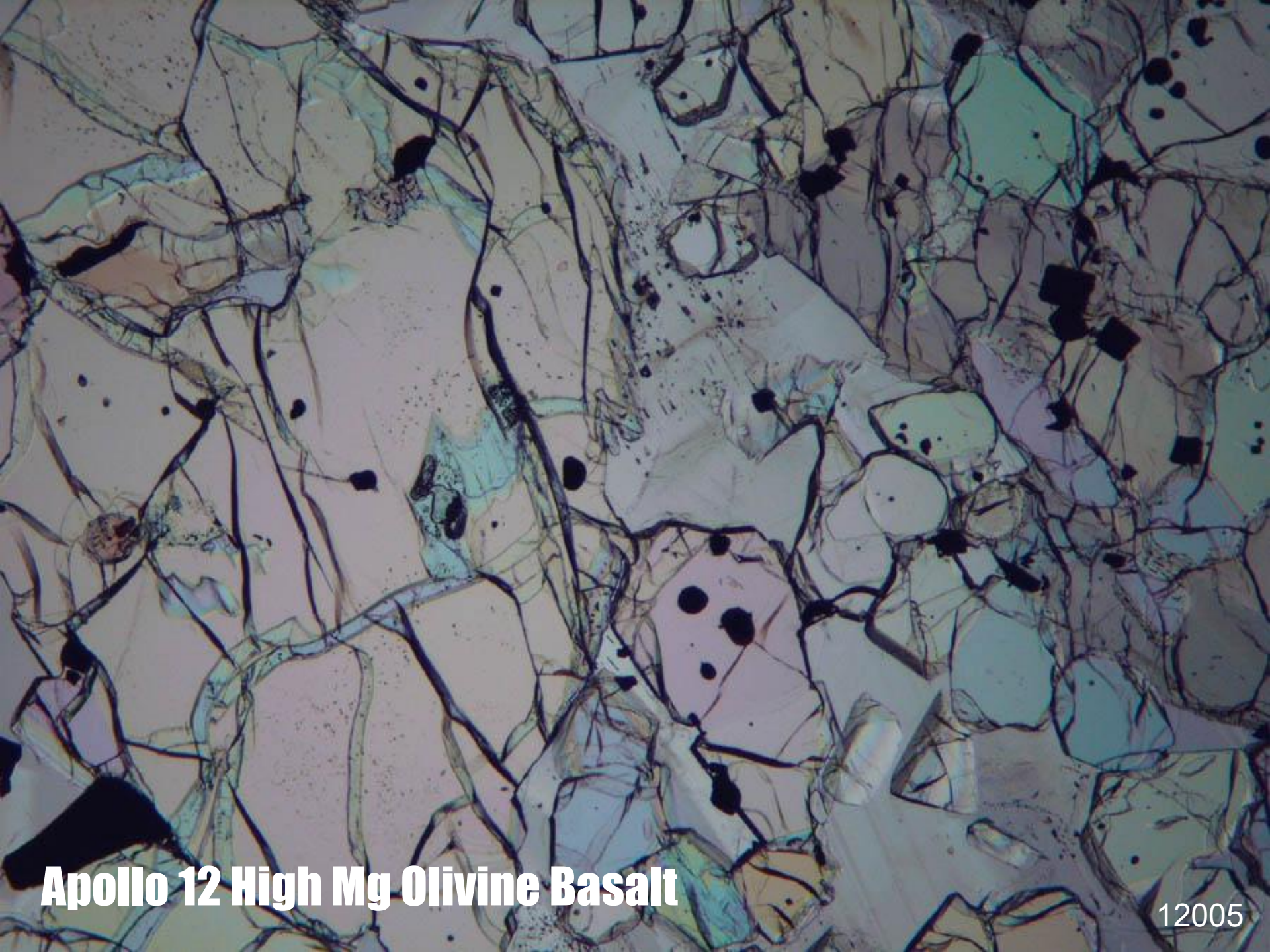
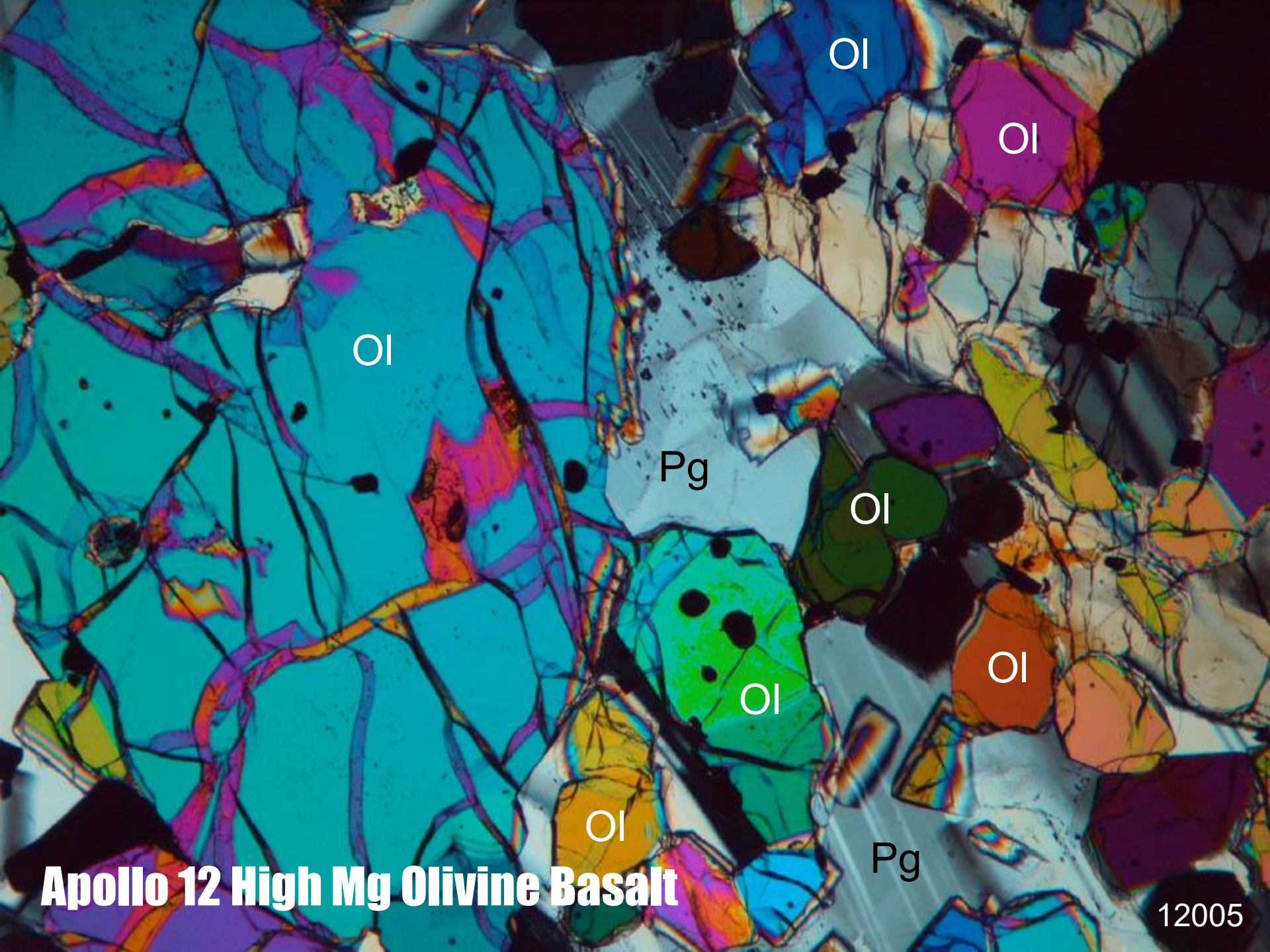

Apollo 12 Porphyritic Basalt
Cpx
Cpx
12002


Apollo 12 High Mg Olivine Basalt
12005


Ol
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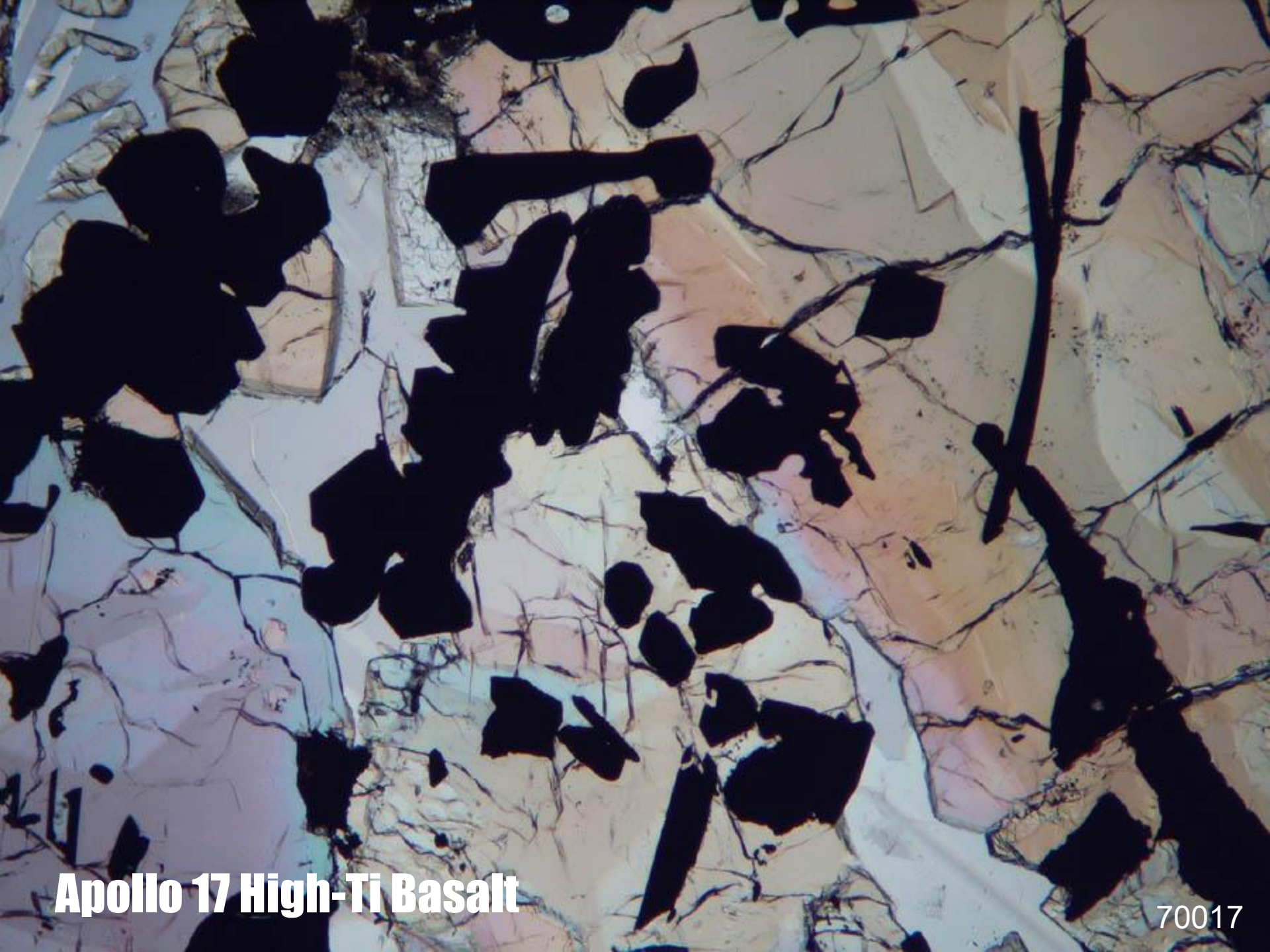
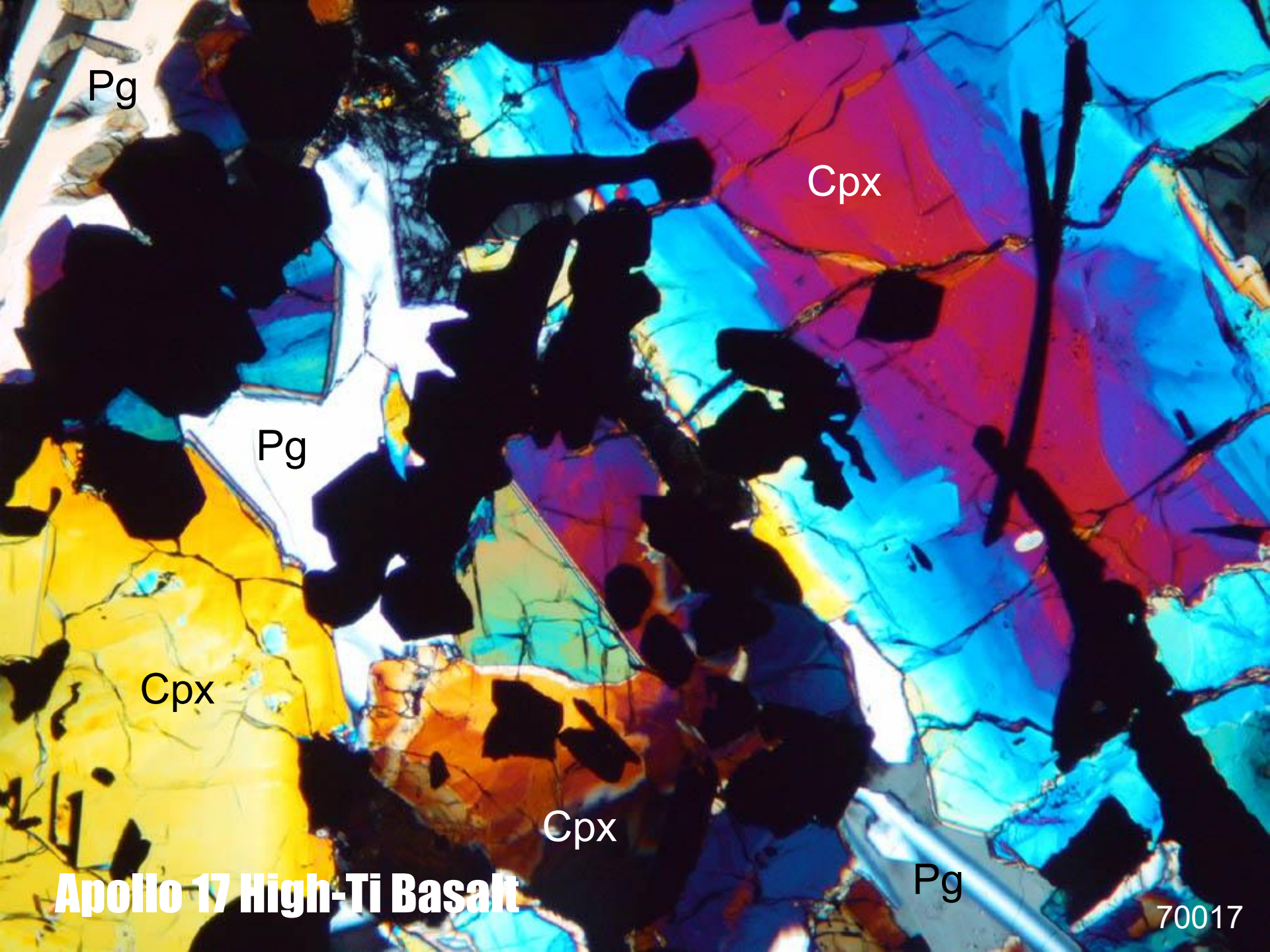
Apollo 12 High Mg Olivine Basalt
12005


Apollo 17 High-Ti Basalt
70017


Pg
Cpx
Pg
Cpx
Cpx
Pg
Apollo 17 High-Ti Basalt
70017

Thanks For Attending!!

DUKE

See Dukelabs.com
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