

THE DAWN OF THE SPACE AGE

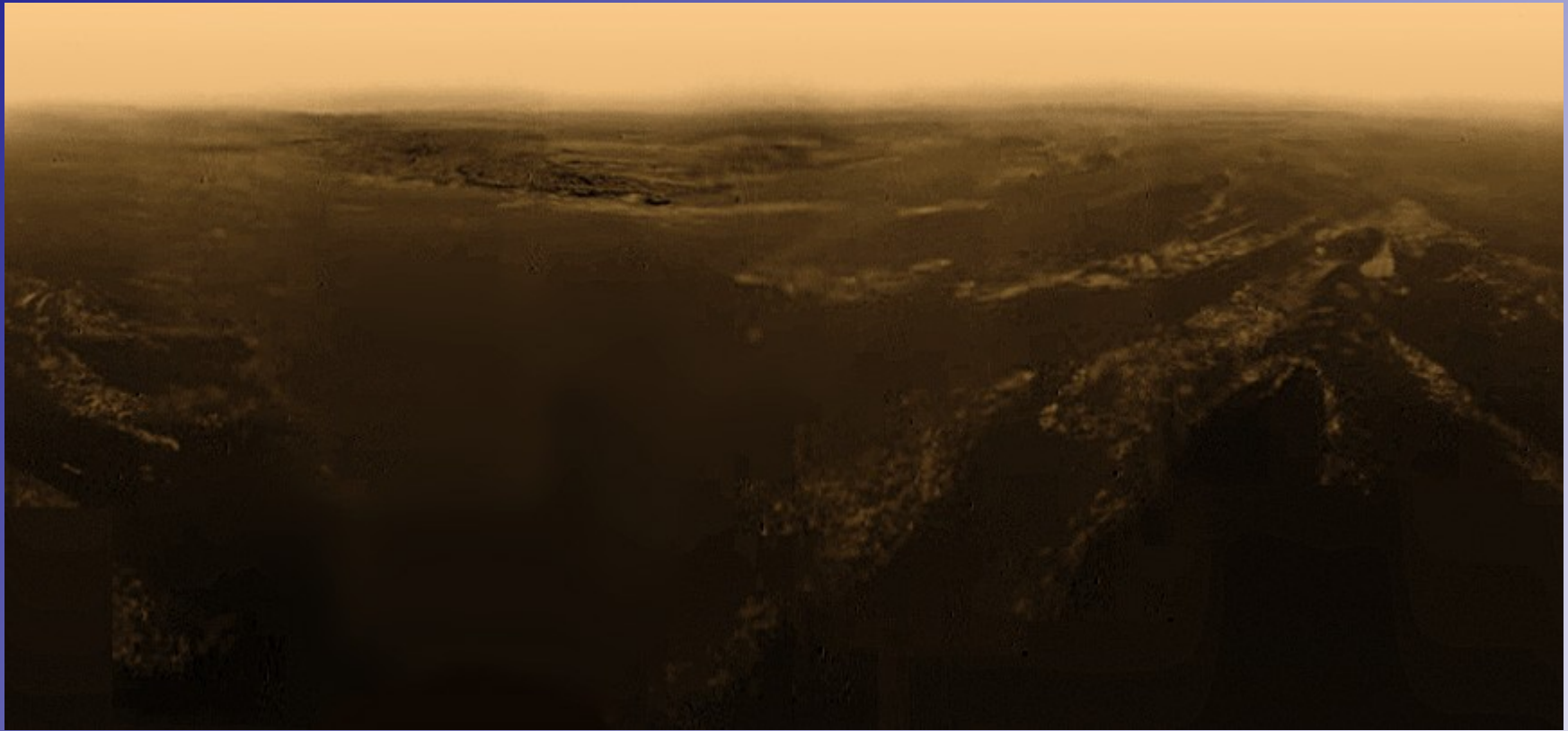


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2005 - Titan

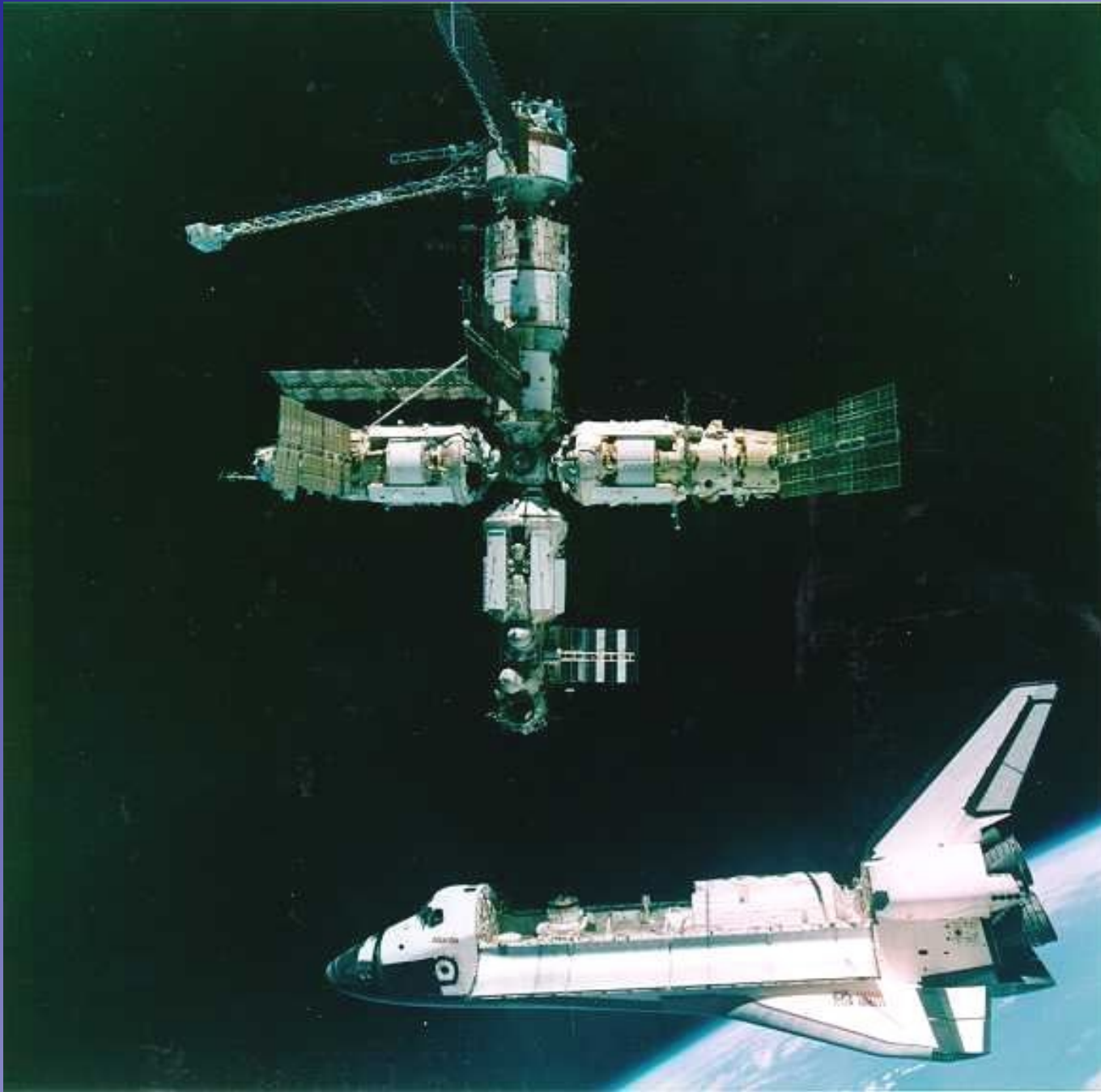


2004 - Spaceship One



Photo by Bill Deaver

1990s: Mir and Shuttle



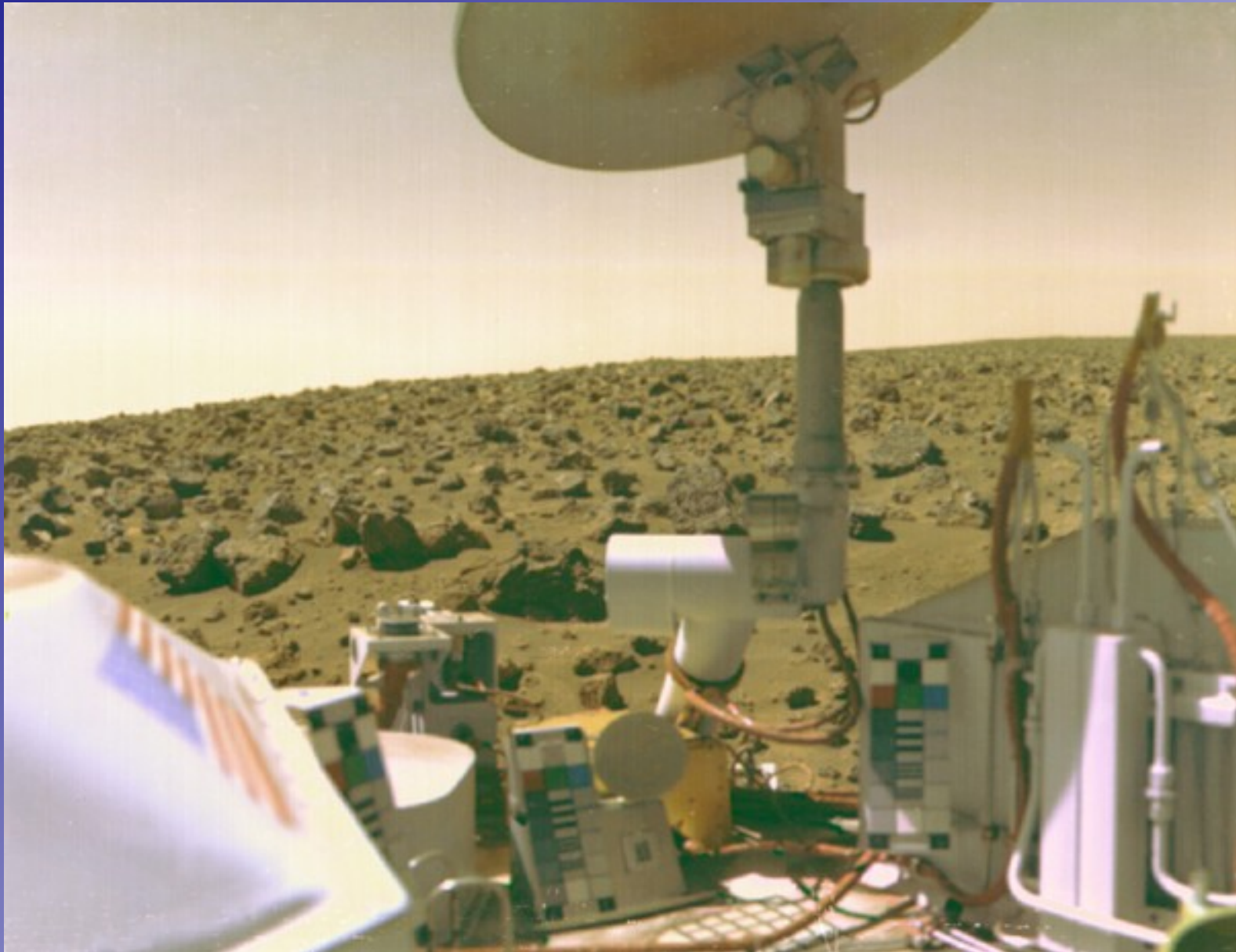
1990 - Hubble Telescope



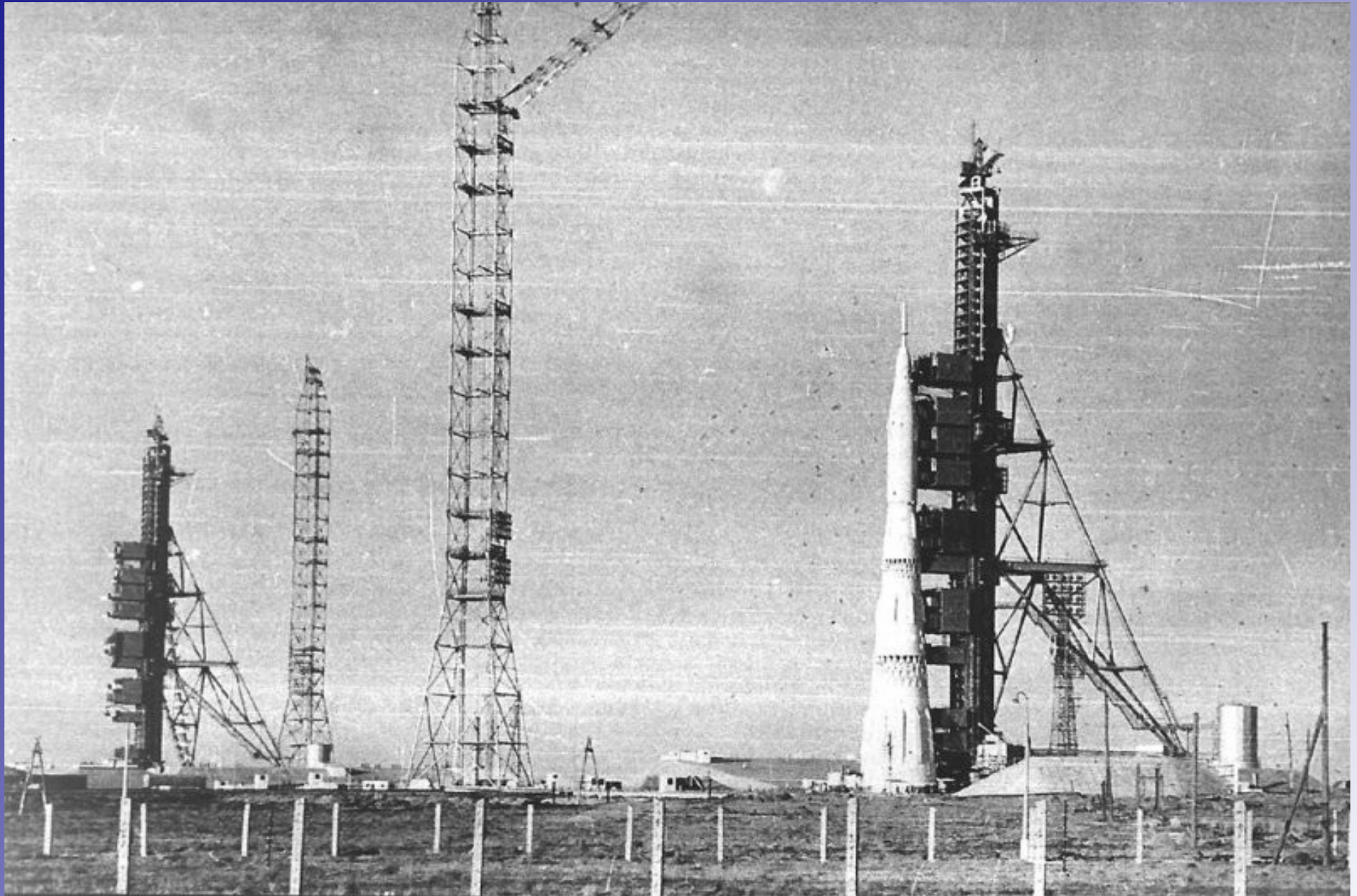
1981 - First Shuttle Flight



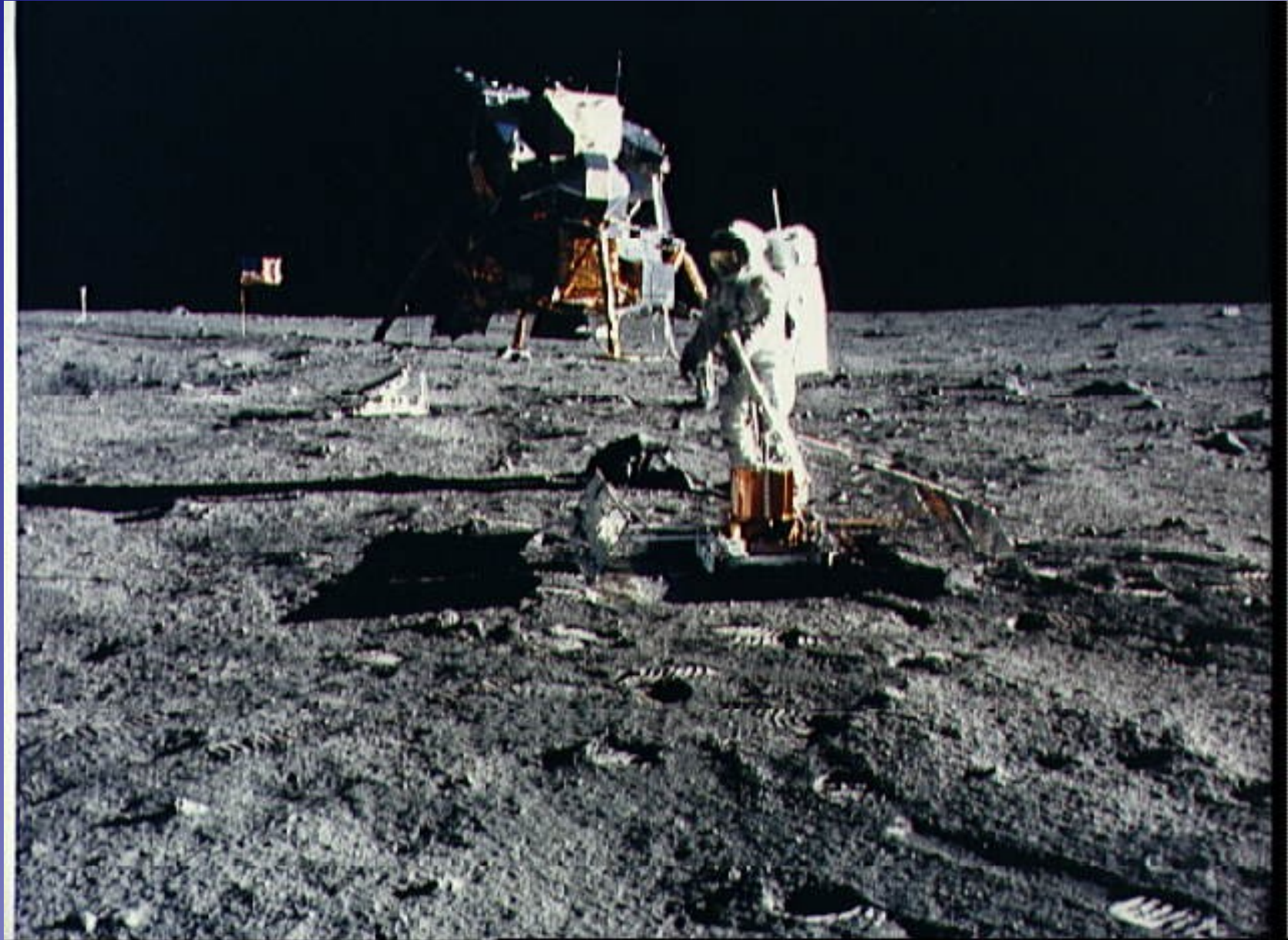
1976 - Viking on Mars



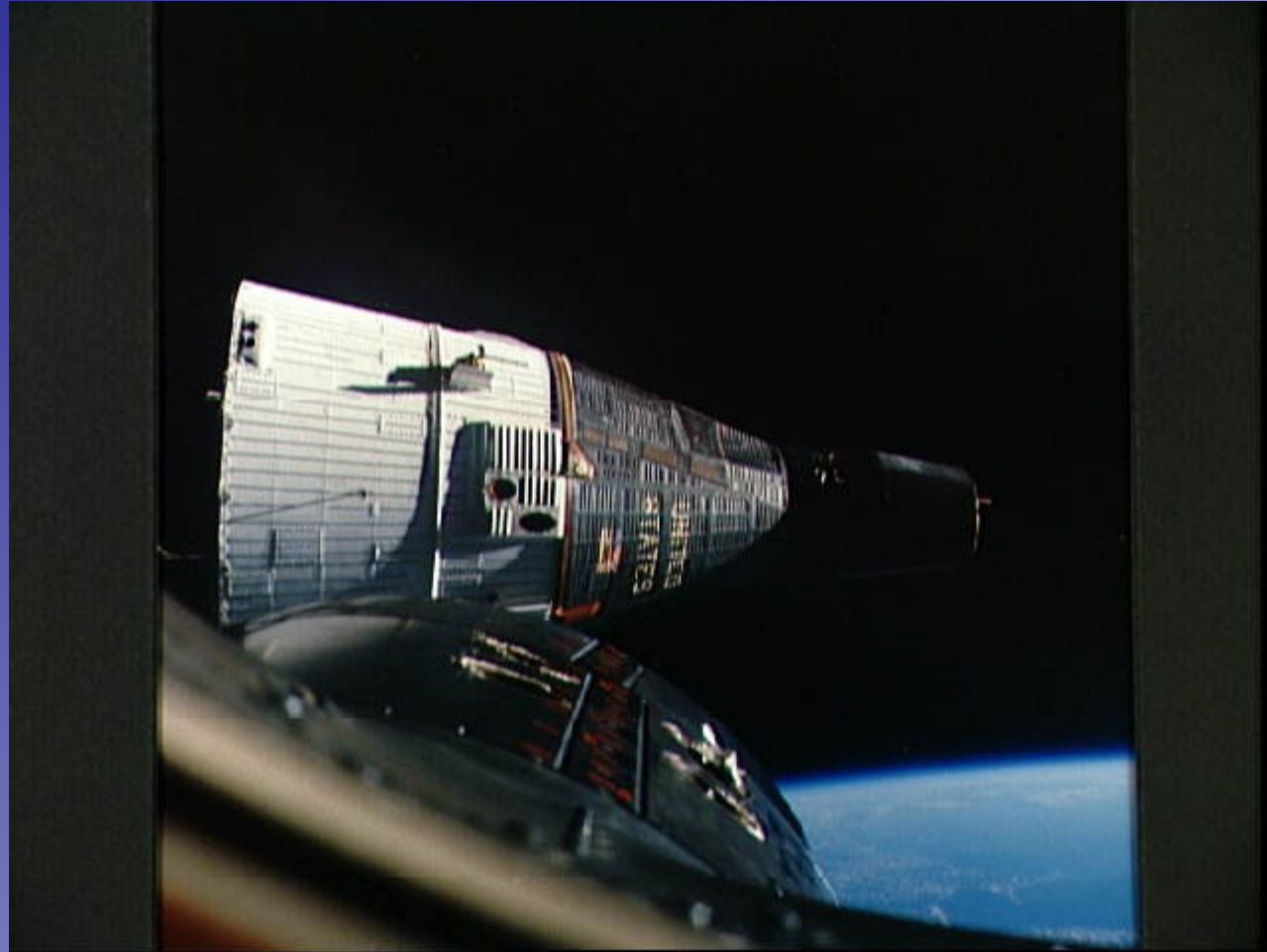
1969 - Soviet Moon Rocket



1969 - Apollo on the Moon



1965-66: Gemini rendezvous and docking



1962: John Glenn orbits Earth in Mercury



“In this decade...”

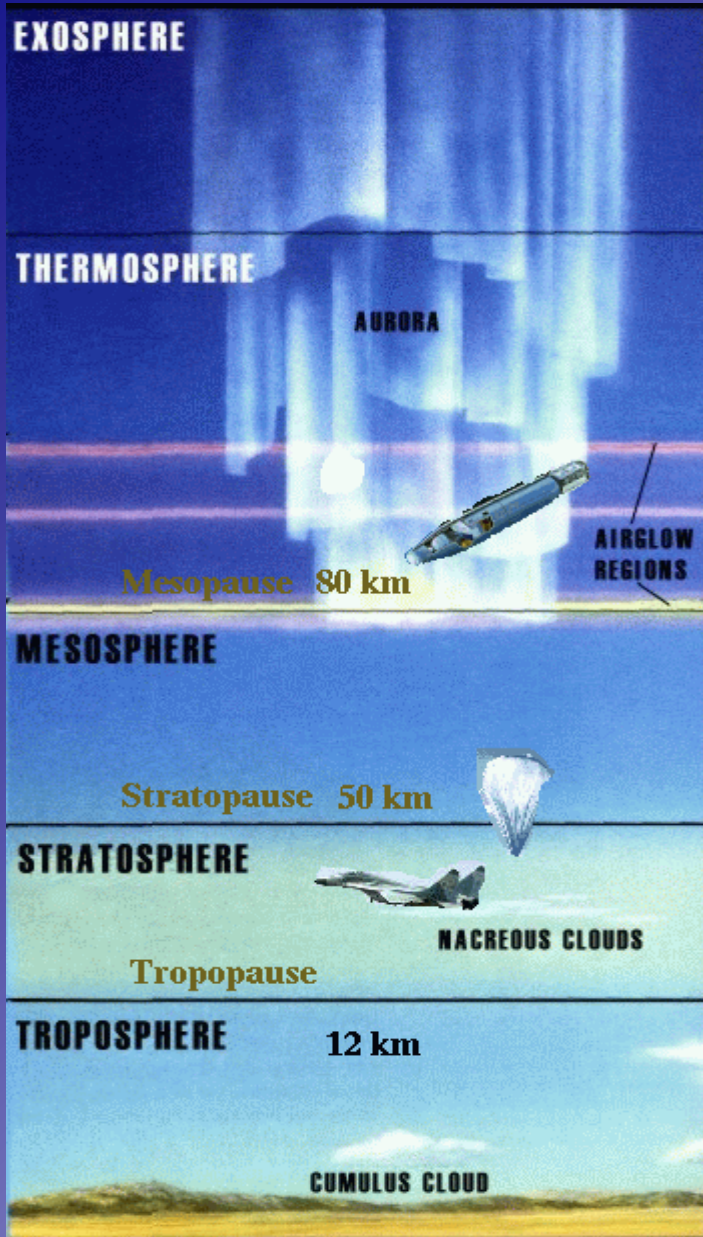


- May 25, 1961: JFK starts the Moon race.
- But the Space Age was already in full flow
- Now the story can be told: US and Russia have declassified their early programs.
- Here is the history of space travel from 1957 to 1961

Plan of talk

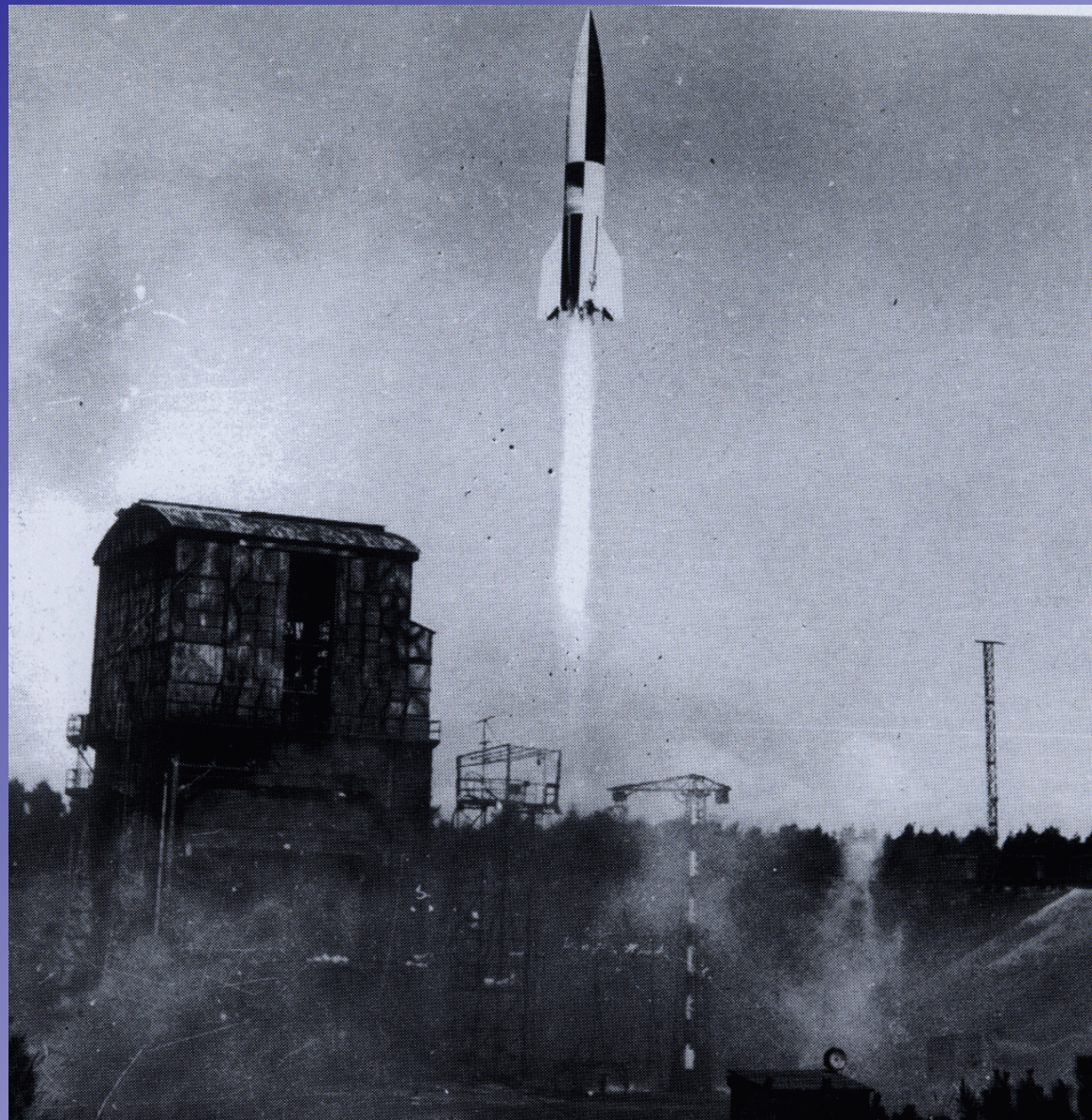
- Statistics of the early space age
- The Soviet space program 1957-1961
- The US space program 1957-1961
- Later developments 1961-1963 (if time)

THE EDGE OF SPACE



- Highest airplanes 38 km
- Highest balloons 51 km
- Lowest satellite perigees 90 km (high apogee or freq. reboost)
- Physics: highest transition layer is mesopause at nominal 80 km
- Tradition: USAF gave astronaut wings at 50 mi.=80 km
- I adopt 80 km as a natural boundary

October 1942: First into space

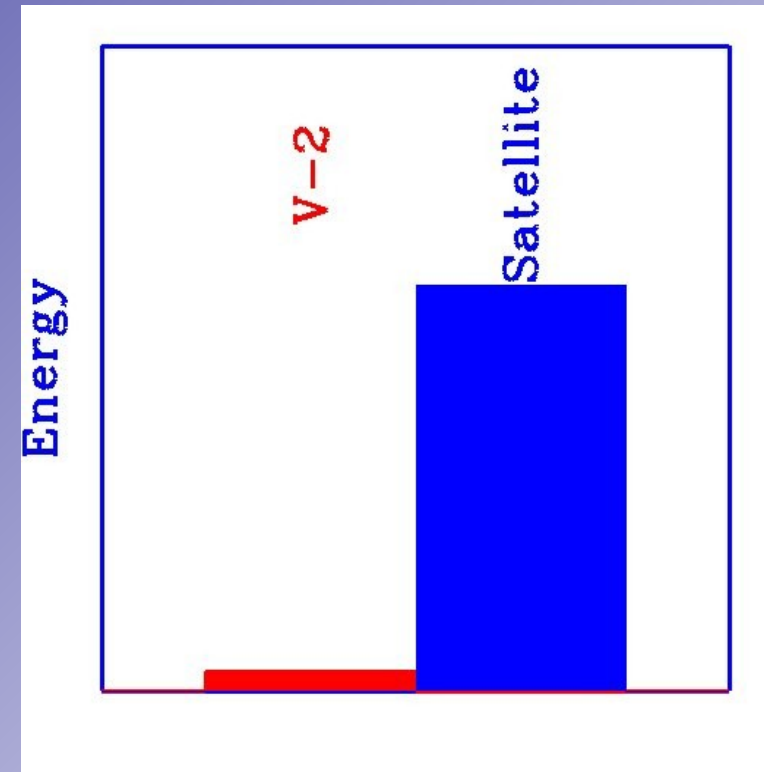


Early space launches (suborbital)

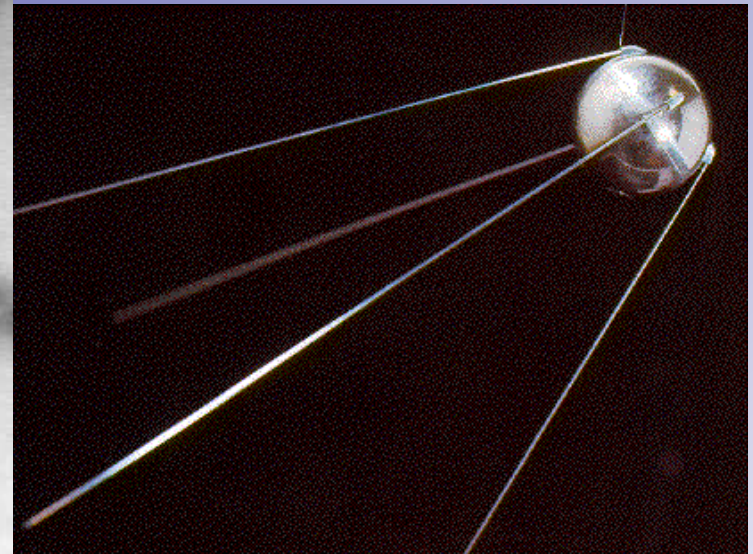
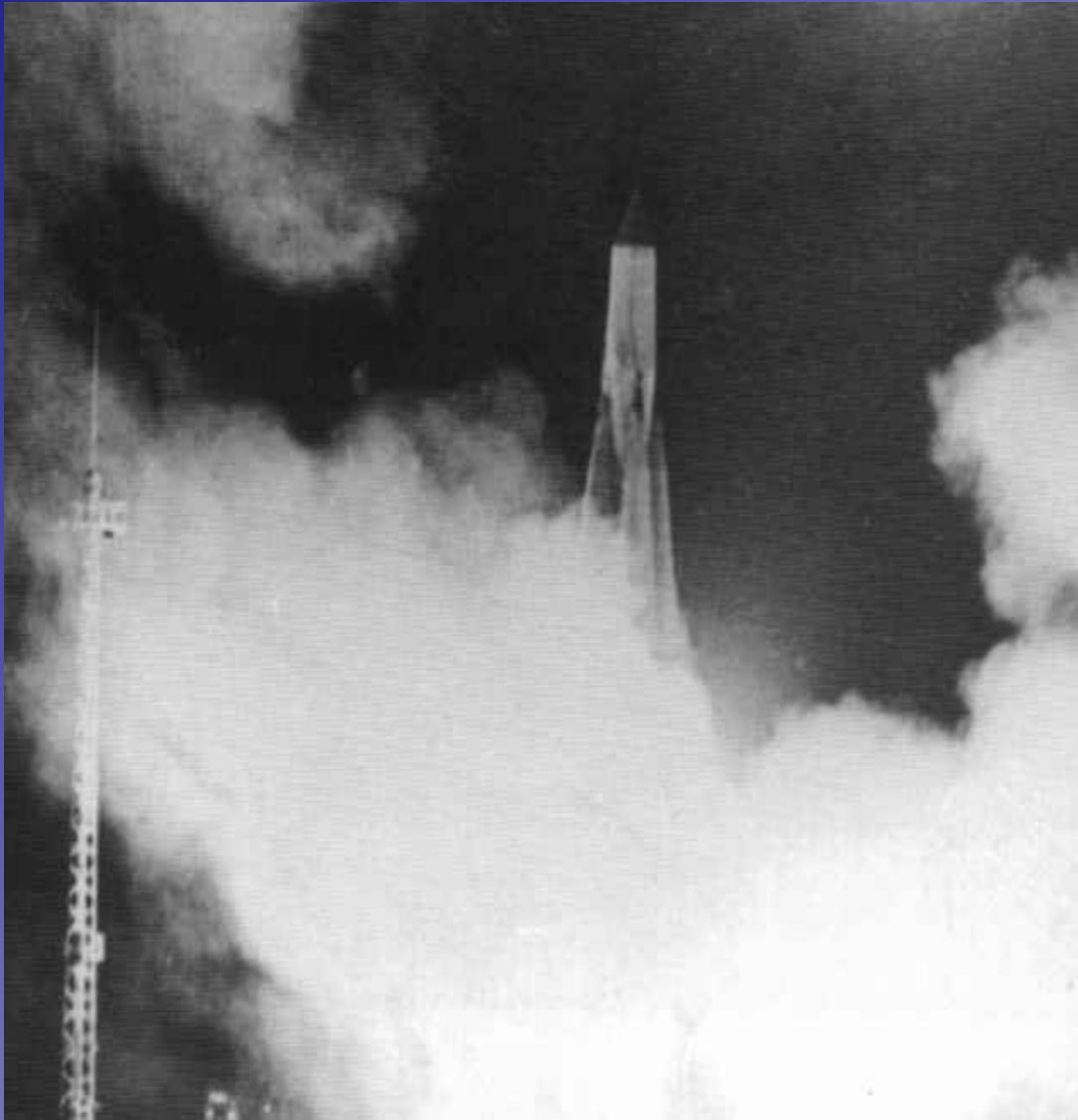
- Germany (Peenemunde): 1942 Oct 3 (or 1943 Mar 18?), V-2
- USA (White Sands): 1946 May 10, V-2
- USSR (Kapustin Yar): 1947 Oct 18, V-2
- France (Hammaguir): 1954 Feb 21 , Veronique
- UK (Woomera): 1957 Jul 23, Skylark
- Japan (Akita): 1960 Jul 11, Kappa-8
- Canada (Churchill): 1960 Oct 12, Black Brant 2
- China (Jiuquan): 1960 Nov, R-2 (V-2 derivative)
- Italy (Sardinia): 1961 Jan 12 with US Nike Cajun
- India (TERLS): 1963 Nov 21 with US Nike Apache
- India (SHAR): 1971 Oct 9 with RH-300 (?)

Getting to orbit

- Consider the “specific energy” (energy per unit mass, KE + PE) of an object in space relative to an inertial point on the Earth's surface
- The V-2, moving slowly at the edge of space, had $E = 1.5 \text{ MJ/kg}$ (1.1 to 2.1 for different launches)
- An orbiting satellite at the same altitude needs $E=31.6 \text{ MJ/kg}$. Getting to orbit is MUCH harder! It took 15 more years...



October 1957: Sputnik



Sergey Korolev's Program

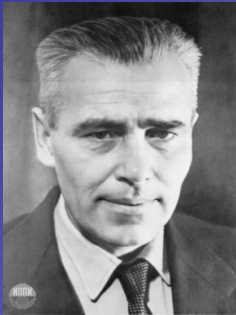


- Soviet Space Programs
- Sputnik
- “D” satellite
- Luna probes to the Moon
- Mars and Venus probes
- Vostok – the first astronaut

The Soviet players



- Sergey Pavlovich Korolev, head of OKB-1 (now RKK Energiya) - Designed Sputnik, Luna, Vostok, Soyuz, etc.



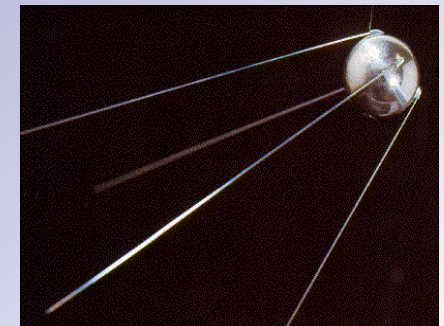
- Mikhail Kuzmich Yangel', head of OKB-586 (now KB Yuzhnoe) in Dnepropetrovsk, Ukraine - designed R-12 (Cuban missile crisis)



- Vladimir Nikolaevich Chelomey, head of OKB-52 (now Krunichev) - ASAT, UR-100, Proton, Almaz
- operated like three independent space agencies

The first orbital launch

- Korolev (OKB-1) R-7 missile, product 8K71
- May 1957 launch failure, Aug 1957 first ICBM
- Plan to uprate engines: the 8A91 rocket for orbital launches, slipped to 1958 (Sputnik 3), related to 8K74 operational ICBM
- Quick and dirty version to preempt Vanguard: the 8K71PS, minimal mods to prototype ICBM version
- PS-1 (Oct 1957) “Simplest satellite”
- PS-2 (Nov 1957) carried dog Laika



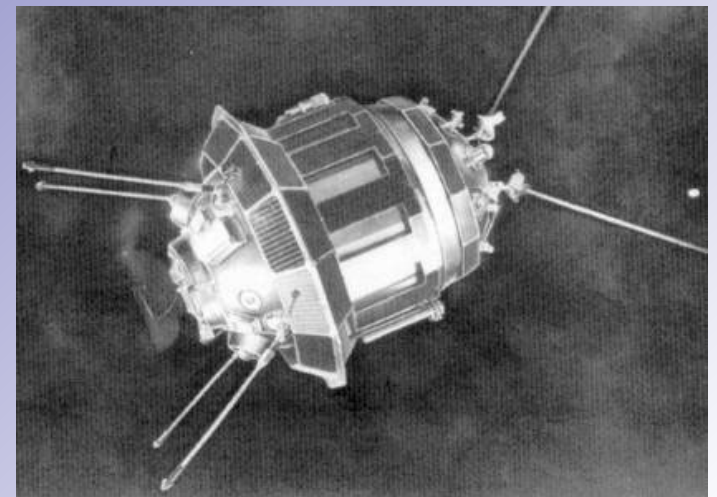
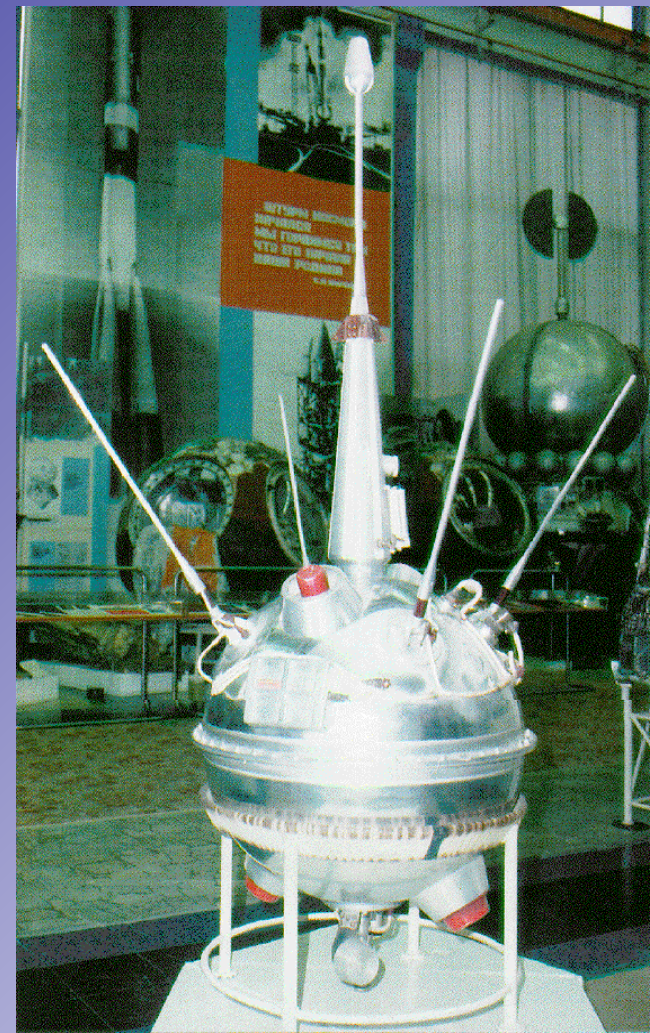
The original “D” satellite

- Object D, 1958 - 2 launches, 1 success (Sputnik-3)
 - 8A91 uprated rocket
 - Feb 1958 launch originally would have been first satellite
 - Preempted by PS-1/2 and Explorer 1
 - Blew up
 - Backup satellite launched May 1958 as Sputnik 3
 - Studied Van Allen belts



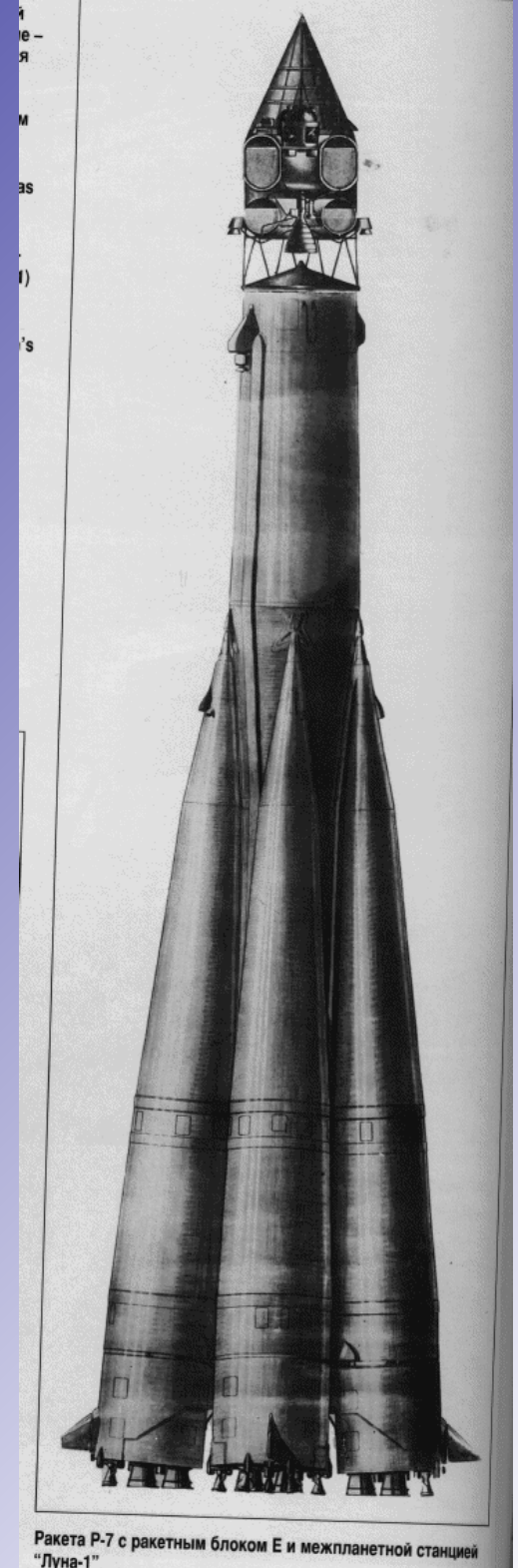
The Luna program

- Silence from USSR from May 1958 to Jan 1959 – what's going on?
- Jan 1959 – First announced Moon probe. Misses Moon and becomes first artificial planet around the Sun
- Used “8K72”, Sputnik rocket with an upper stage
- Sep 1959 Luna-2 becomes first probe to hit the Moon
- Scatters pennants with Lenin's face over Lunar surface
- Oct 1959, Luna 3 photos of lunar far side



The Luna program: new info

- Long-rumoured 1958 launch attempts confirmed: first try in Sep 1958, a month after first Pioneer launch failure
- Object E-1, 1958-1959 - 6 launches, 2 successes
- Previously unsuspected Apr 1960 launch attempts were “E-3” Luna-3 circumlunar photo follow-ons
- E-3 No. 1 reached 200000 km apogee but was not tracked by USA
- Next series was E-6 landers, starting in 1963



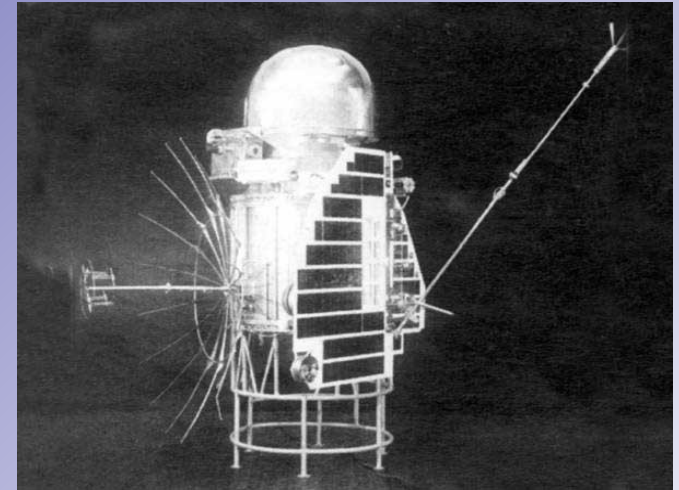
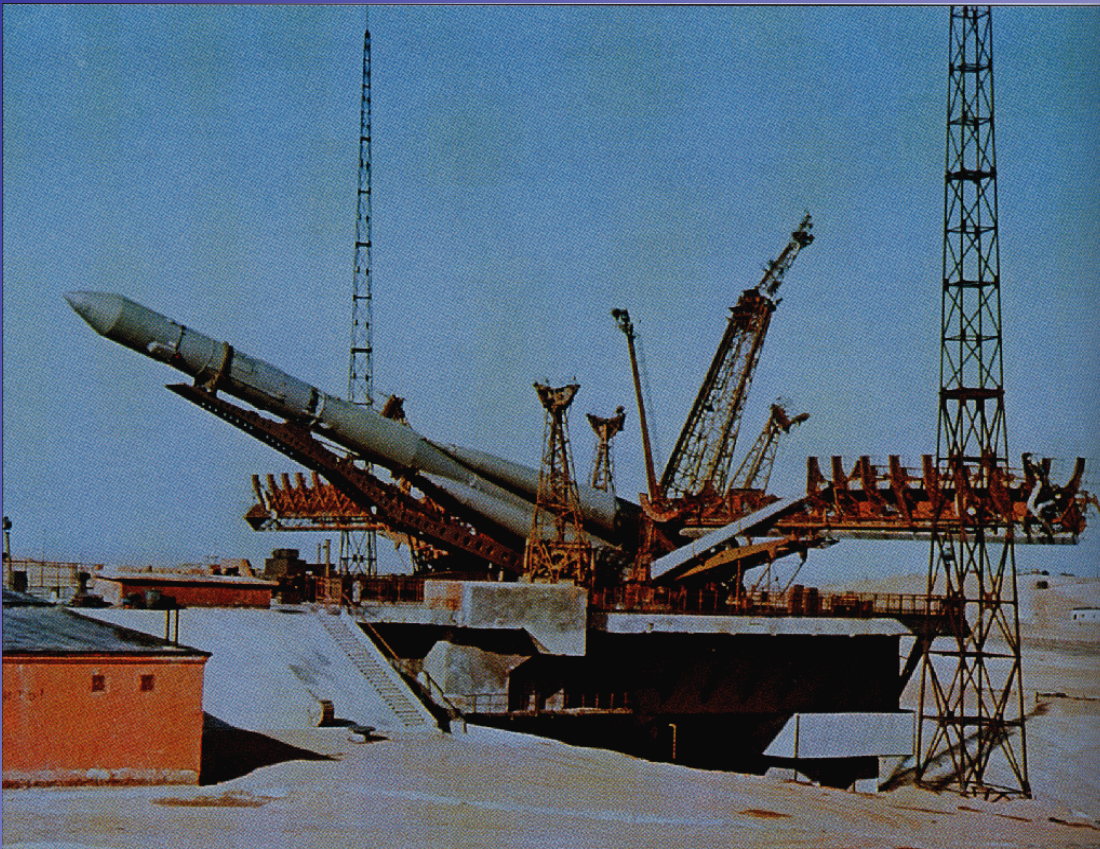
Mars and Venera

Early USSR planetary program was unsuccessful.

Stick yet another upper stage on Sputnik rocket –
the four-stage 8K78 “Molniya”

Mars probe (1M) launches in 1960, blew up

Venus probe (1VA) launches in 1961, failed



Vostok

- Apr 12, 1961: Yuriy Gagarin becomes the first astronaut aboard “Vostok 3KA No. 3”

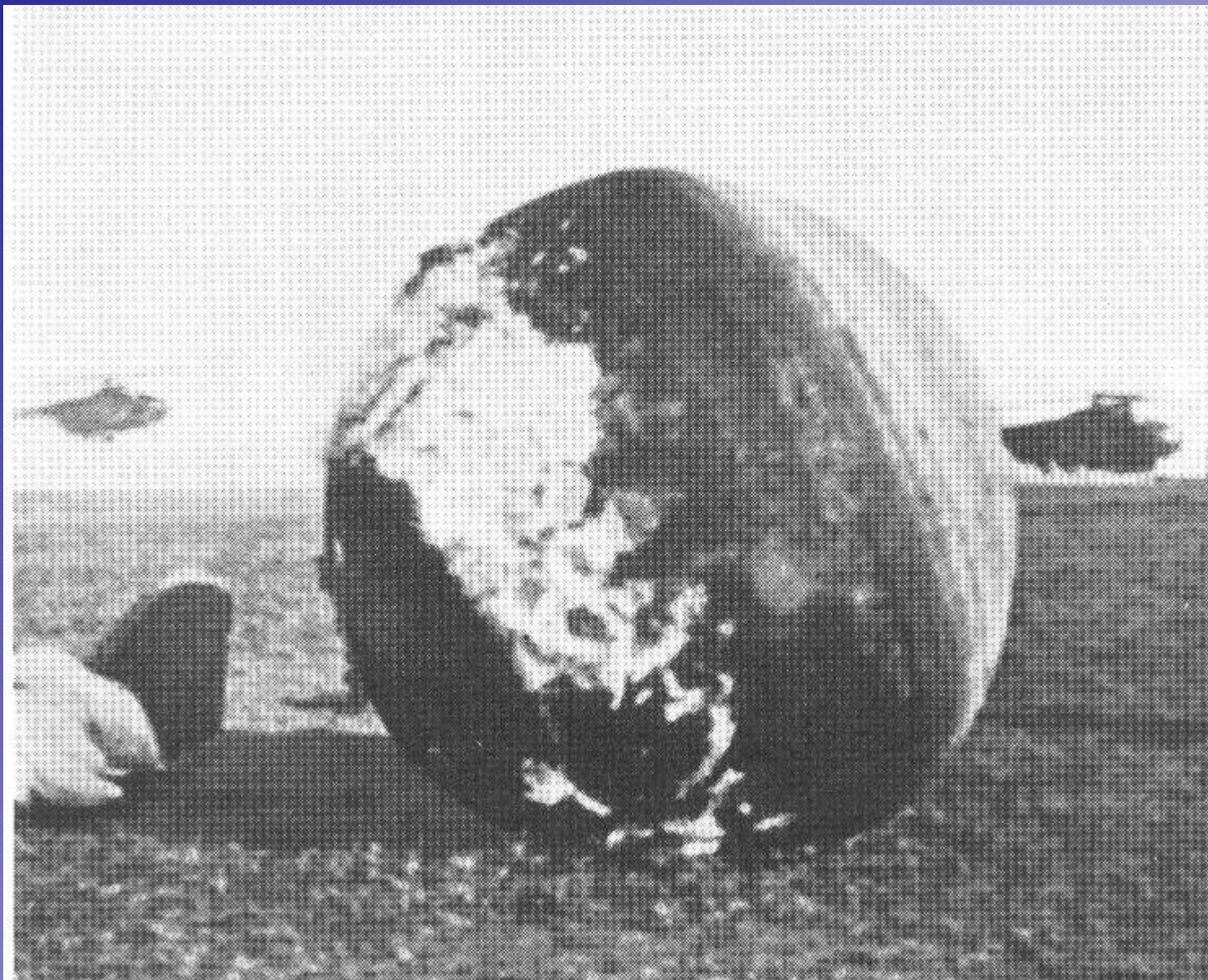


Vostok in orbit

- Spherical cabin
- Double-cone instrument module with liquid retrorocket



Vostok landing



The Vostok program (1)

- Vostok used the 8K72K rocket, which was a Sputnik with the Blok E upper stage like that used for the “E” lunar missions
- The first launches, without astronauts, were announced as “Korabl'-Sputnik” (Spaceship-Satellite)
- The 1K prototype was followed by the 3KA human-rated version and later the 3KV/3KD multiseater (Voskhod)

The Vostok program (2)

- May 1960 test launch - retro fired in wrong direction
- July 1960 1K No. 1 crashed near launch site
- Aug 1960 1K No. 2 - dogs Belka and Strelka first living things recovered from orbit
- Dec 1960 1K No. 3 - destroyed in reentry
- Dec 1960 1K No. 4 - launch failure crashed in Siberia
- Mar 1961 3KA No. 1 - dog recovered safely after 1 orbit
- Mar 1961 3KA No. 2 - dog recovered safely after 1 orbit
- Apr 1961 3KA No. 3 - Yuri Gagarin's flight
- Aug 1961 - Jun 1963: Titov, Nikolaev, Popovich, Bykovsky, Tereshkova all fly successfully

Other Soviet programs

- All these programs (PS, D, E/Luna, Mars, Venera, Vostok) were run by Korolev and used his R-7 (8K71) rocket and its derivatives
- Vostok was modified as a spy satellite in 1962; derivatives still fly for science missions
- The Yangel program, with “DS” (Dnepropetrovskiy Sputnik) satellites and the R-12 booster got going in late 1961, with first success in 1962 under the Kosmos-1 cover name
- The first Chelomei product, an antisatellite development test, flew in 1963.

America in orbit 1957-1961

- Early program run by military and CIA:
 - US Army (ABMA/Huntsville): Explorer, Pioneer (with JPL)
 - US Navy (NRL/Washington): Vanguard
 - US Navy (NOTS/China Lake): “NOTSNIK”
 - US Air Force (WDD/Los Angeles): Able, Samos, Midas
 - CIA (Langley): CORONA (Discoverer)
- NASA formed 1958 for civilian space programs
- NRO formed 1961 for reconnaissance programs

ABMA/JPL Explorer

- Werner von Braun's stretched V-2 with spinning upper stages from JPL and tiny 4 kg payload
- Redstone reached apogee, spinning stages fired horizontally to get orbital velocity

UNCLASSIFIED

JPL TECHNICAL REPORT NO. 32-31, VOL. I

XII. DESCRIPTION OF THE LAUNCHING VEHICLES

A. General Description of Explorer I

The *Juno I* configuration (Fig. 50) is similar to that of the *Jupiter-C*, but with the addition of a fourth stage and

a payload. Other changes included a different shroud, over the stage 2 motor domeheads, and a new high-performance fuel—unsymmetrical dimethylhydrazine (UDMH) and diethylene triamine (DETA) in the booster.

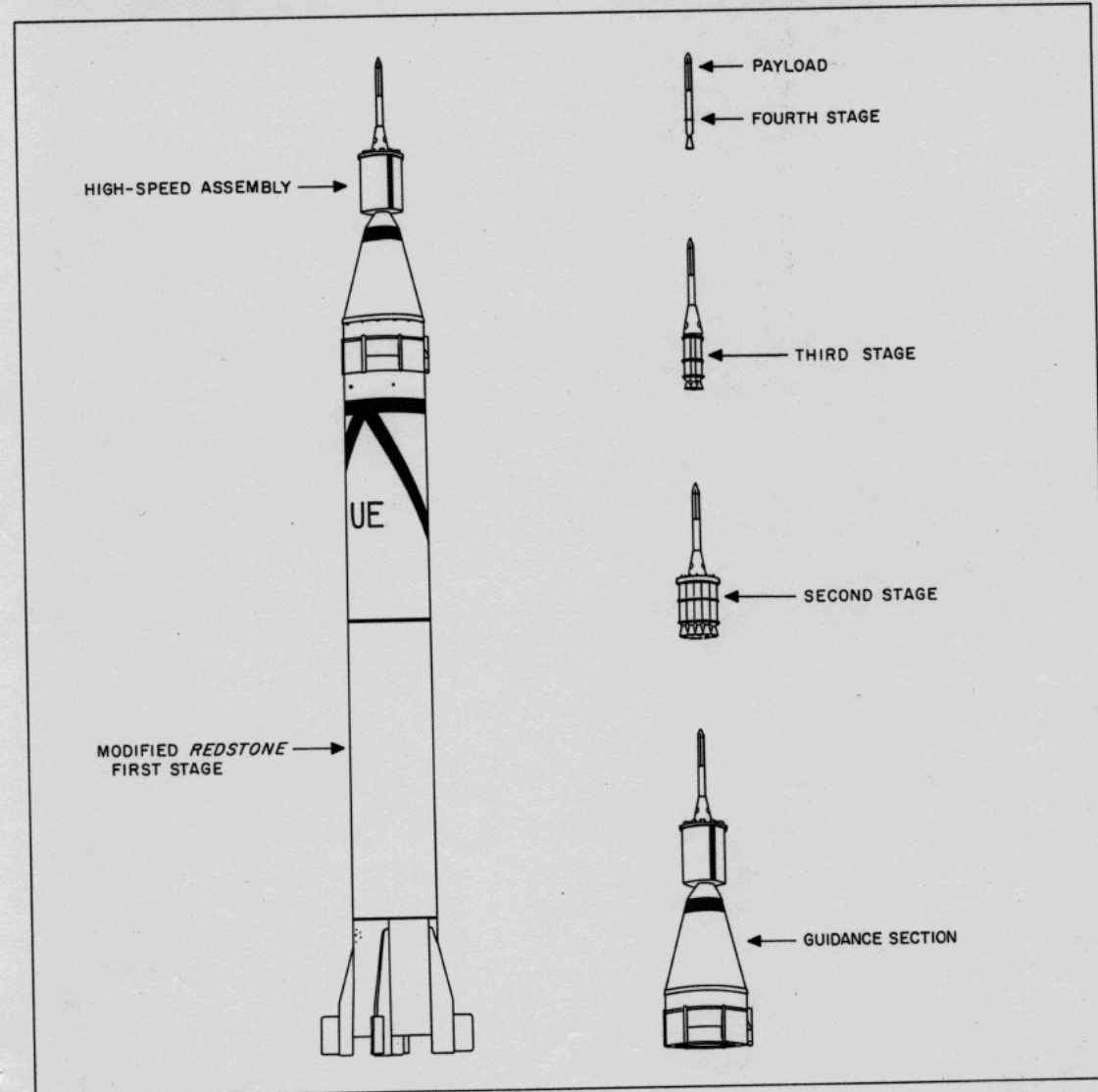
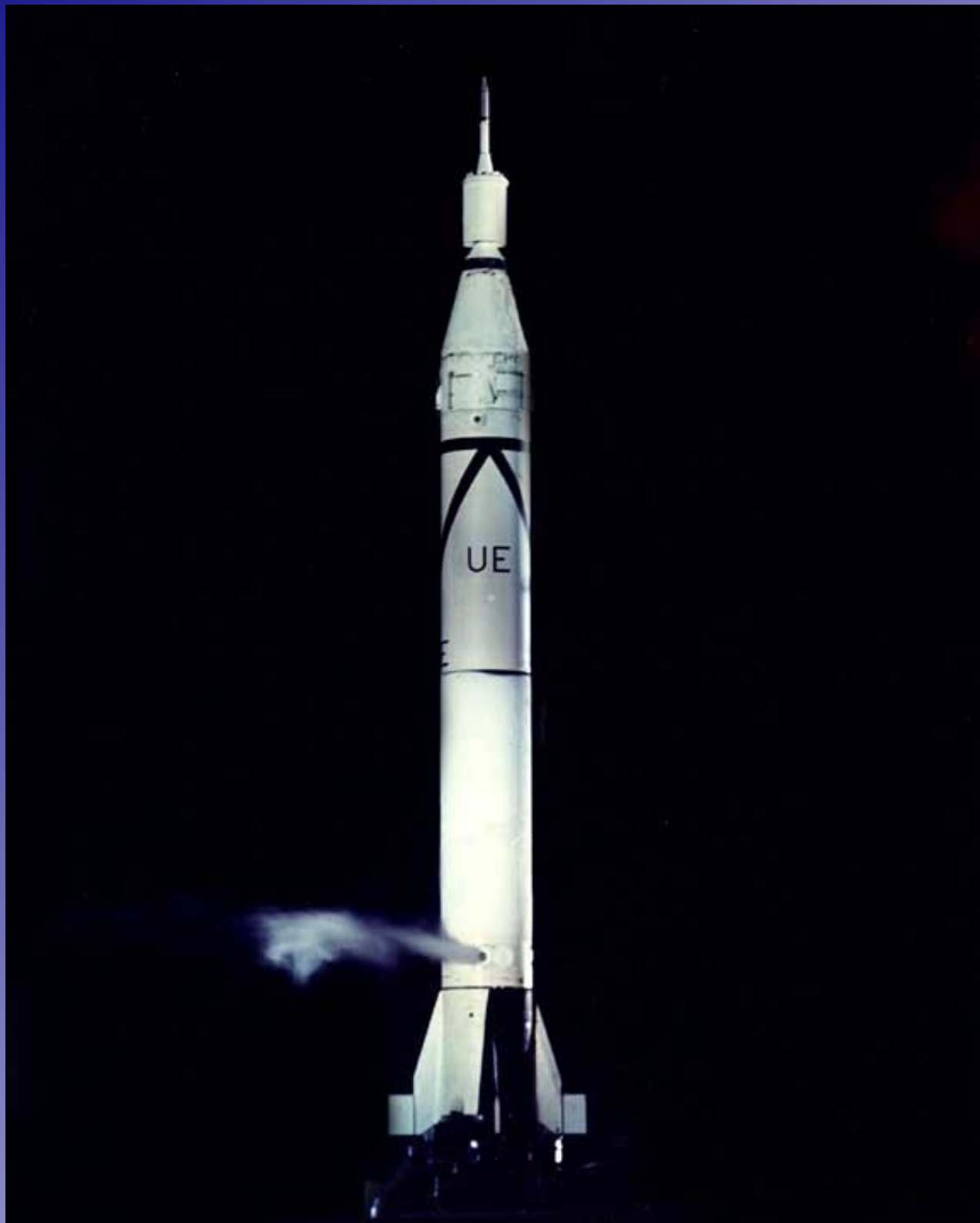


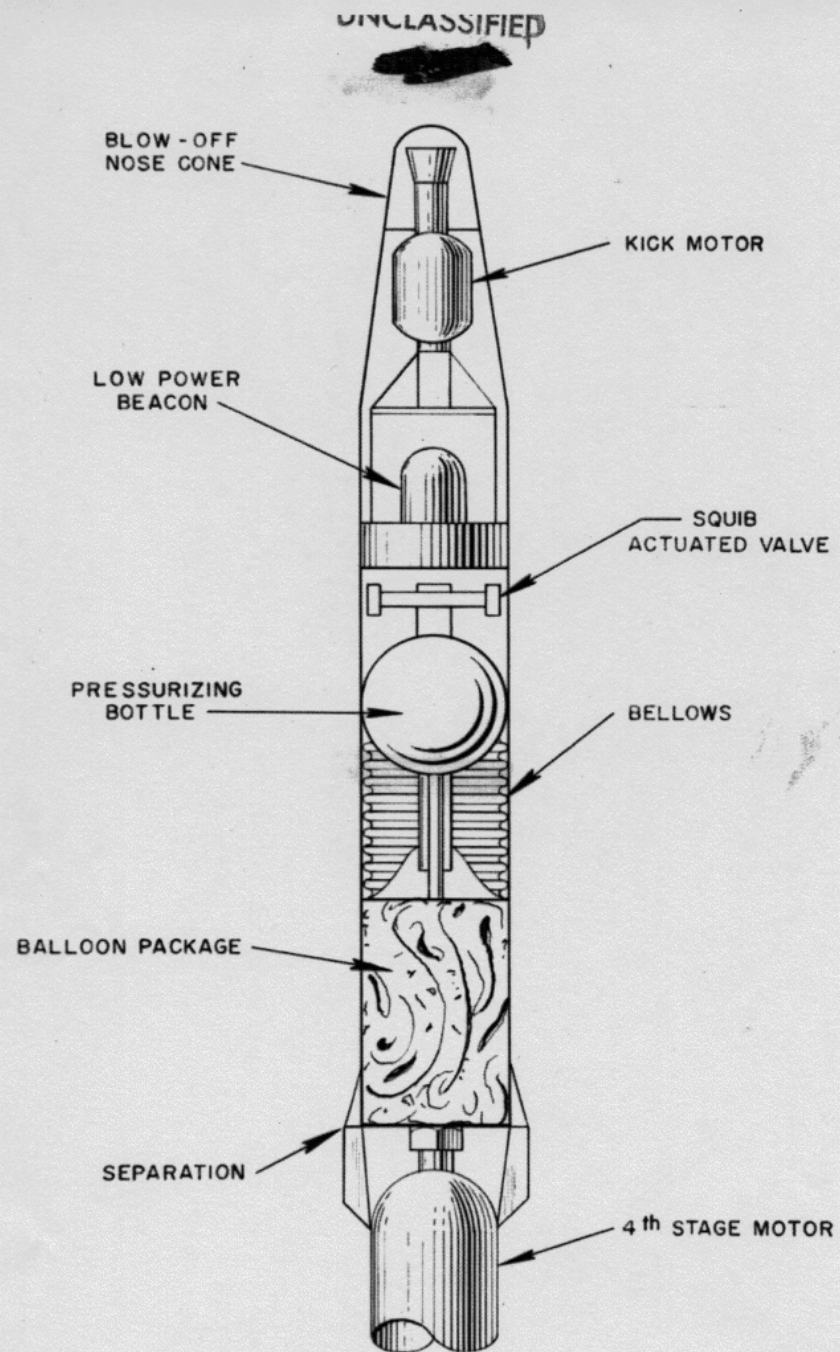
Figure 50. The *Jupiter-C*

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A Kick In the Apogee

- First ever apogee motor (1 kg mass)
- Alas, fell in ocean; first full success not till Syncom 2 in 1963
- Pickering (JPL) coined “kick in the apogee” - hence, “Apogee kick motor”
- Independent invention by USN NOTS team

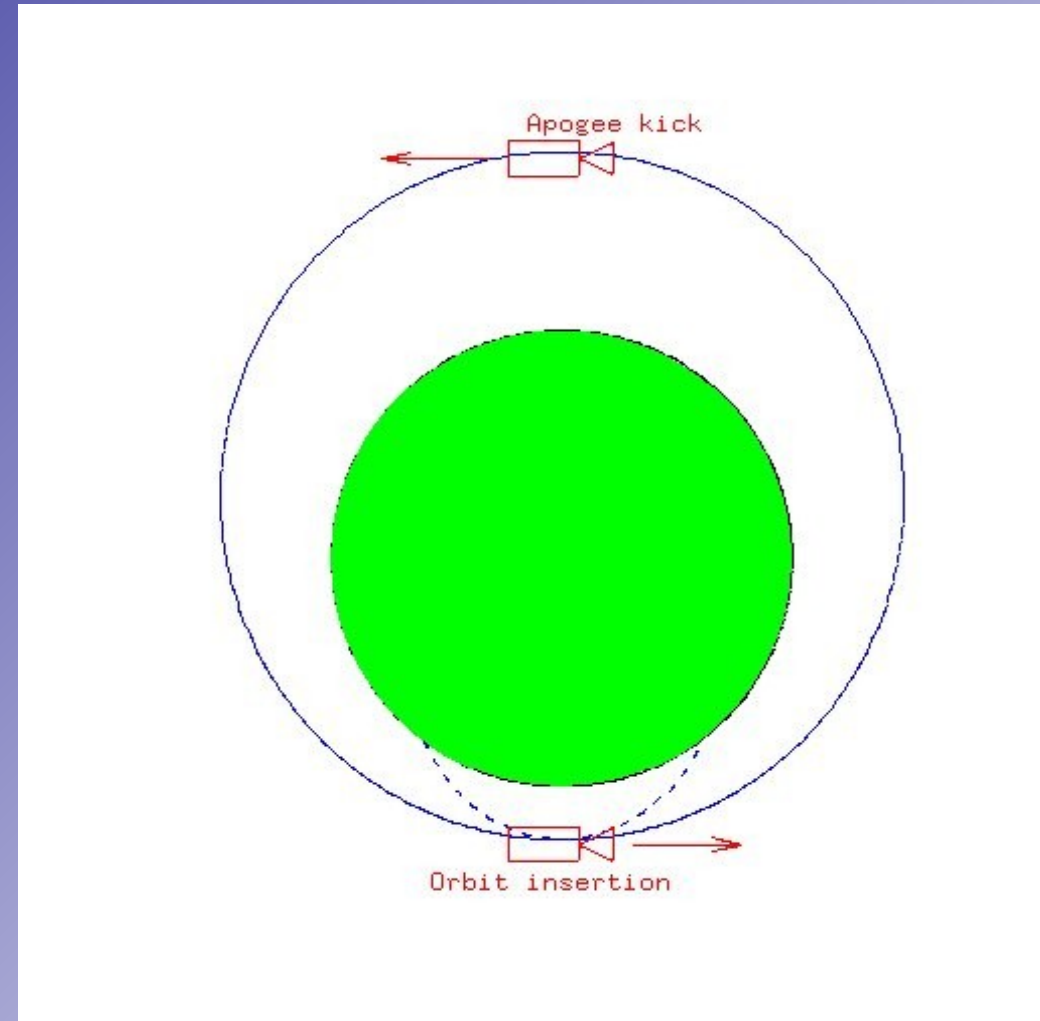


JUNO I Missile 49 Payload

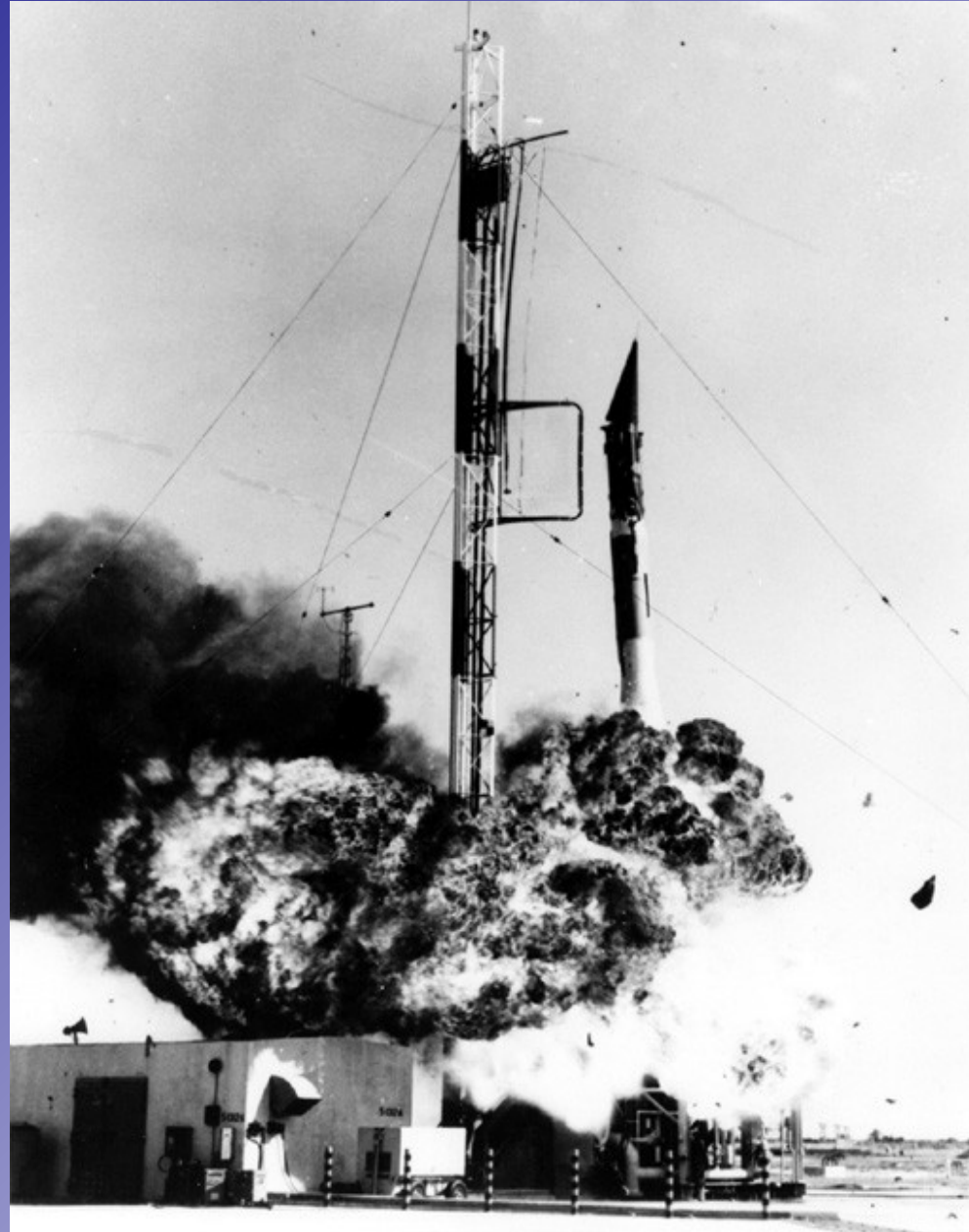
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Apogee kicks

- Early launches all had upper stages coast to apogee then burn for orbit insertion. Resulting orbits have low perigee, short lifetime.
- Add an extra stage to fire after 1/2 orbit, raise perigee to match apogee - circular orbit with long lifetime
- Launch motor upside down, rely on spin and timer for correct orientation 1/2 orbit later

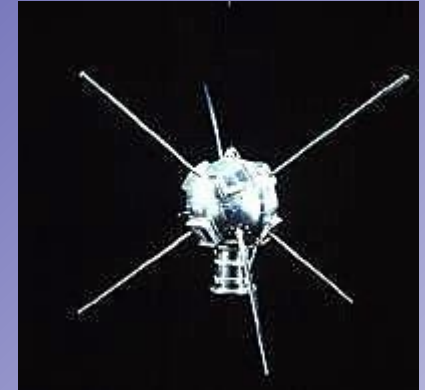


NRL's Vanguard



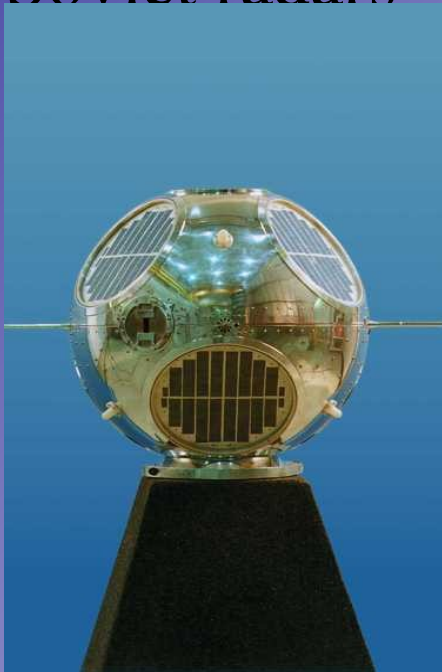
NRL's Vanguard

- Bad rep - but stage 2 and 3 used for Delta with success
- Early launches used 2 kg test satellite - success on 3rd try
- Standard “Vanguard sphere” was 51cm - 2 of 8 made orbit
- Some of the Vanguard team went to Goddard to do science satellites, but some stayed at NRL
- Now we know: the Vanguard 51-cm sphere satellite had a later, secret history



Secret Vanguard: GRAB

- 51-cm spheres used
- “SOLRAD” solar physics cover story
- First signals intelligence sat, studied Soviet radars



Piggy-Back Satellites Hailed As Big Space Gain for U. S.

By Charles Cordry
United Press International

Two new American satellites circled the earth today after a spectacular "double-header" launching with a single rocket. Officials hailed their success as proof that America is "moving into space for real."

The moonlets, launched piggy-back fashion from Cape Canaveral, Fla., at 1:34 a. m. EDT Tuesday, were sent aloft to provide the world a precise all-weather navigation system, to improve the accuracy of its clocks and to measure the sun's radiation.

The larger satellite also carried a space experiment for Canada—a receiver to study background radio noises from the galaxies.

America now has 11 satellites in orbit around the earth, compared with Russia's two.

New Space First

The feat of putting up a pair of satellites simultaneously with a single booster was a new space "first" for the United States. This has not been attempted, so far as is known, by Russia.

A two-stage, Thor-able-star, an Air Force rocket, accomplished the feat.

The Transit II-A satellite, the navigational aide and time-measuring sphere, soared into a near-circular orbit that will carry it over all of the earth's land masses—including Russia—except certain arctic and antarctic points.

As soon as orbit was achieved, this 223-pound aluminum space probe gave birth to the smaller basketball-sized satellite, which checks on solar radiation. It was ejected by spring action.

Payloads Function

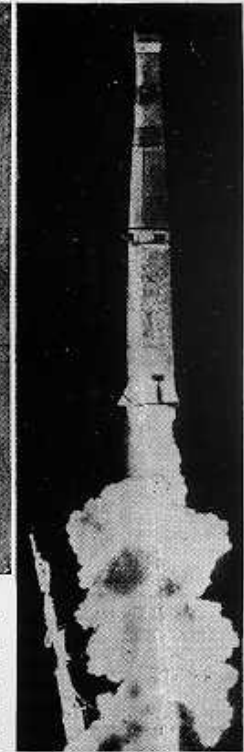
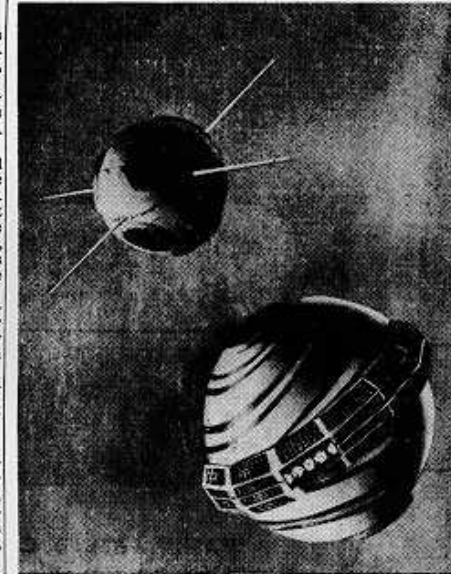
Rear Adm. T. F. Connolly, chief of the Navy Bureau of weapons, told a news conference here that the payloads of the two satellites were functioning properly.

"There are no problems," he said.

Cmdr. R. F. Freitag of the Weapons Bureau said Navy officials are confident now that a system of four Transit satellites, to be in operation by 1962, will be able to fix positions on land and sea within one-tenth of a mile.

The first Transit, launched last April, is giving fixes within a quarter of a mile, they said, and the one launched yesterday will do better.

When all four Transits are in orbit, ships at sea can interrogate them by radio at any time regardless of weather and



Associated Press

The drawing above shows how the Transit II-A satellite and its "piggyback" package, a solar radiation measurement satellite, appeared just after separation in outer space yesterday. The larger satellite was developed by the Applied Physics Laboratory of Johns Hopkins University at Silver Spring and the smaller vehicle by the Naval Research Laboratory here. At right: the double-header satellite rocket takes off at Cape Canaveral.

the satellites will give them "fixes" in code that will tell them where they are.

Moving for Real

Connolly said the launching of a pair of satellites with a single rocket showed that space operations are becoming "something we can count on."

"We are rapidly moving into space for real," he said.

R. B. Kershner of the Johns Hopkins Applied Physics Laboratory said the navigation satellite's orbit was taking it to a maximum of 563 miles from earth and bringing it to within 460 miles.

Its orbiting time is 101.5 minutes. The orbit is inclined 65 degrees to the equator.

The smaller, 42-pound solar radiation sphere probably has taken "bathed" Transit II-A, Kershner said. It will settle into a somewhat larger orbit and circuit the earth more slowly.

The II-A, in addition to the

Canadian experiment, carries a new feature not on the first Transit satellite—an electronic

or "digital" clock which the Navy said could "lead to a new global time system."

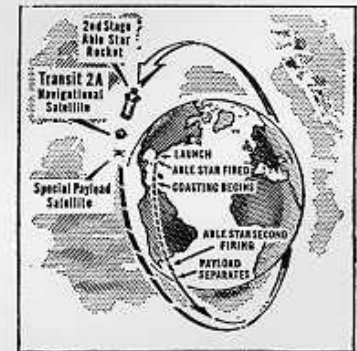
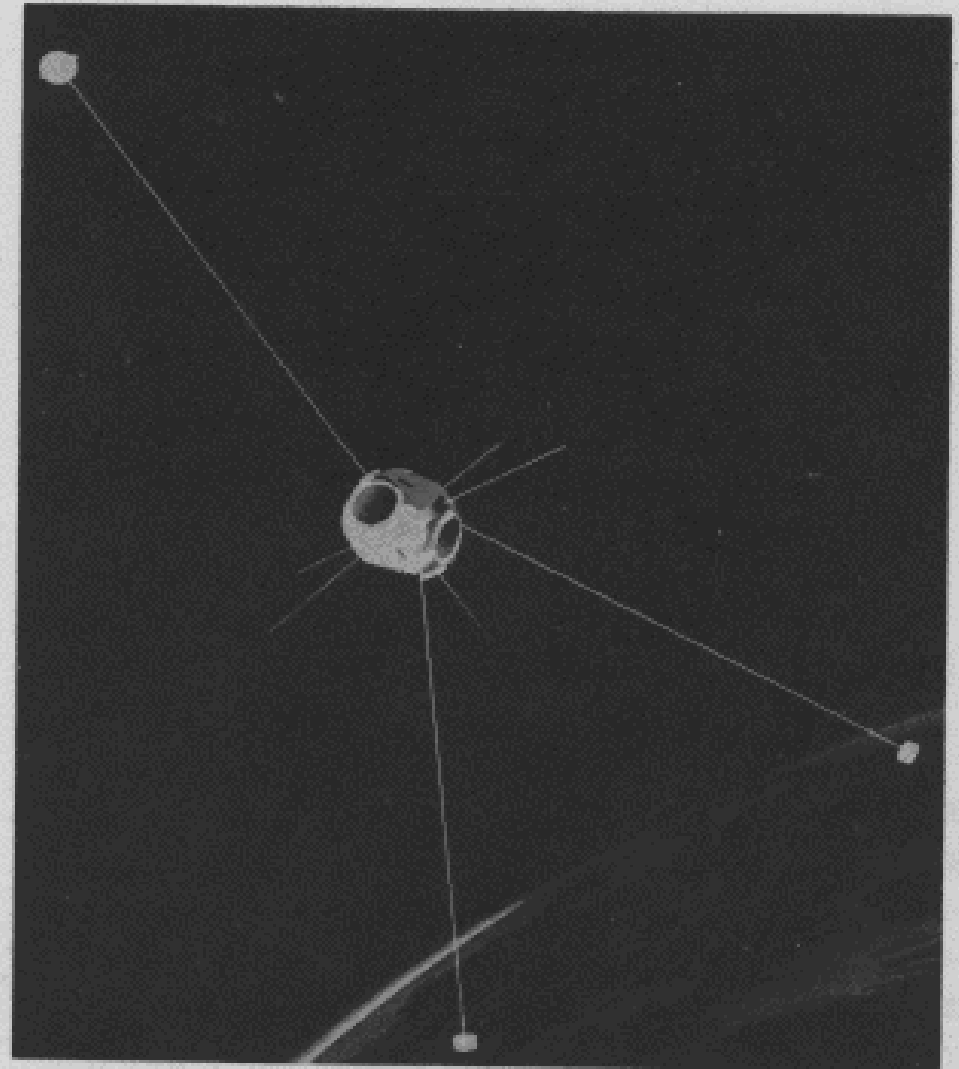


DIAGRAM SHOWS ORBIT ... of "mother and daughter" satellites

Secret Vanguard: GGSE

- Early gravity gradient experiments
- Also used for formation flight tests which led to radio interferometer surveillance satellites
- Last 51-cm Vanguard sphere launched in 1967? Last derivative 61-cm sphere launched in 1971. Vanguard legacy much longer than usually reported.



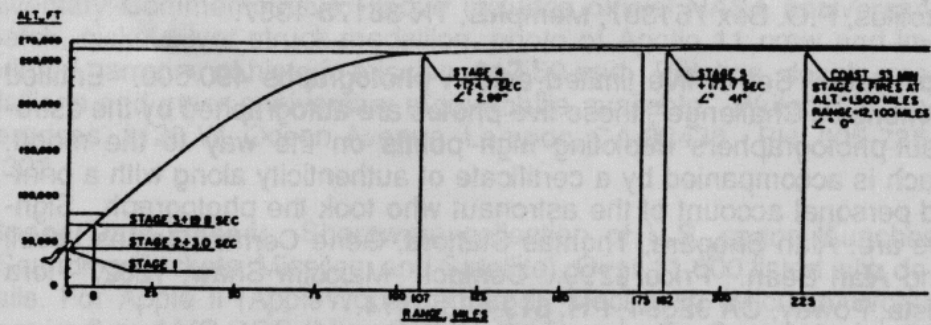
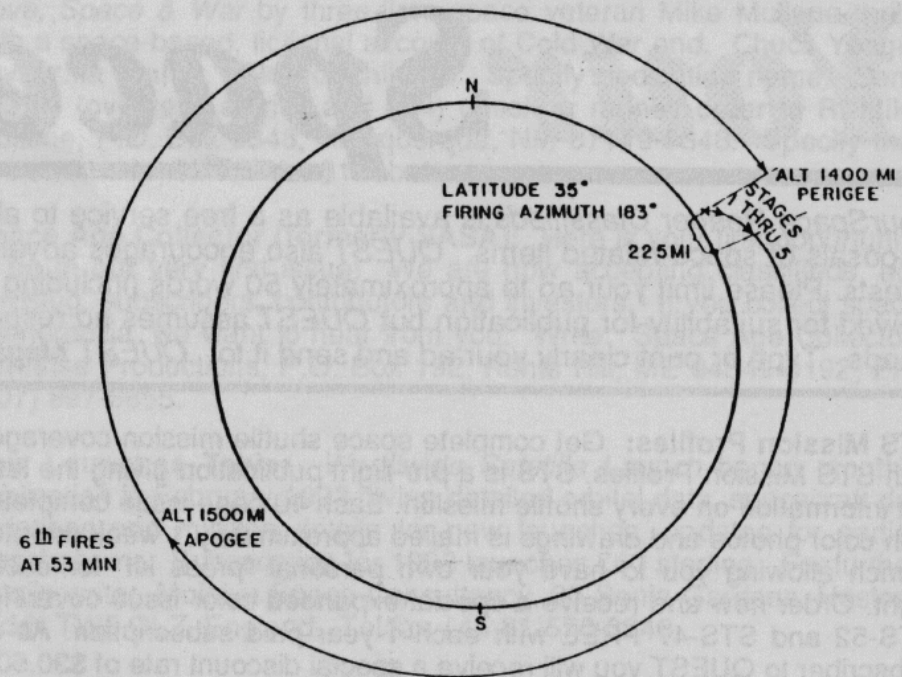
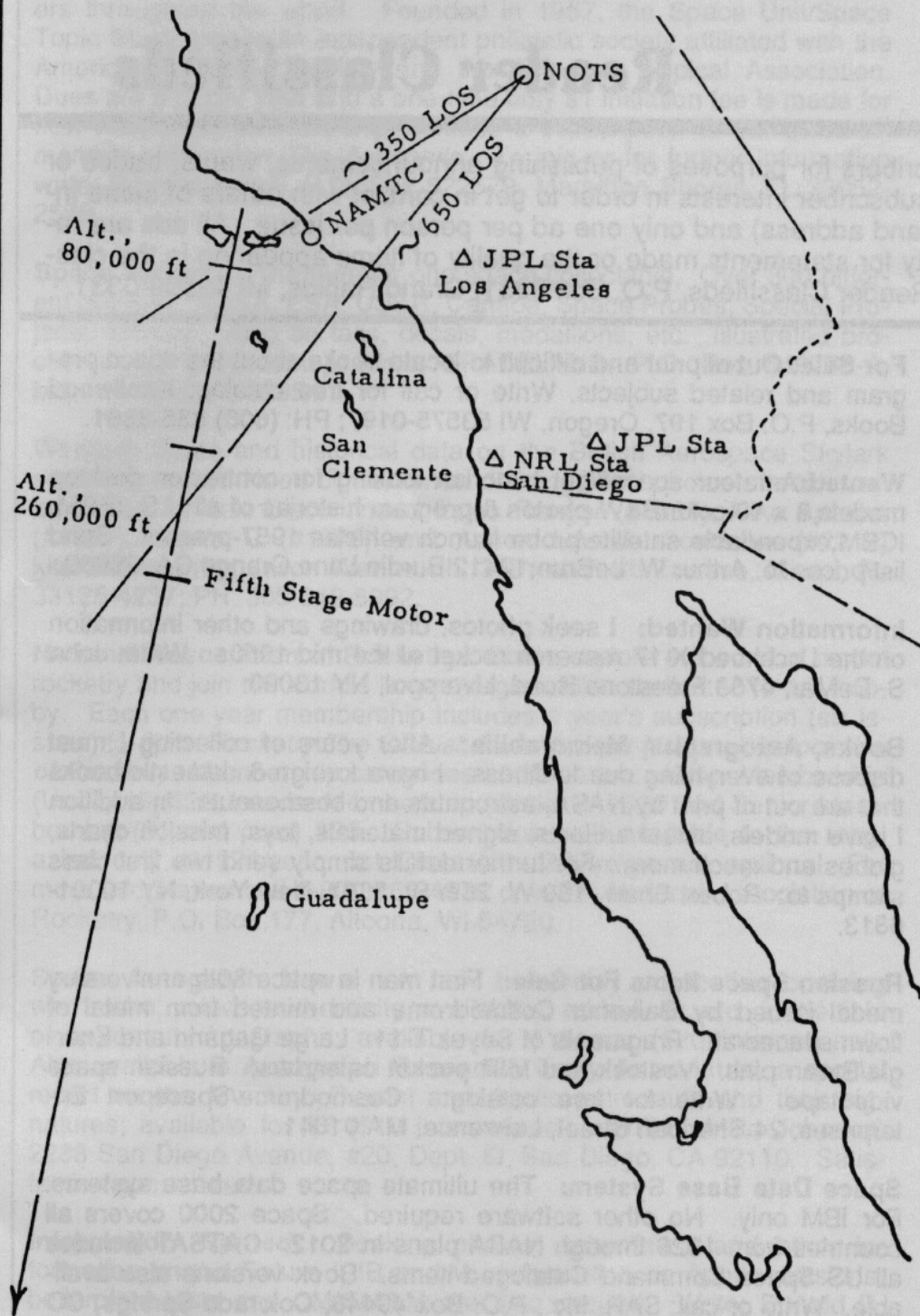
(c) Experiment III.

NOTSnik - Jul/Aug 1958



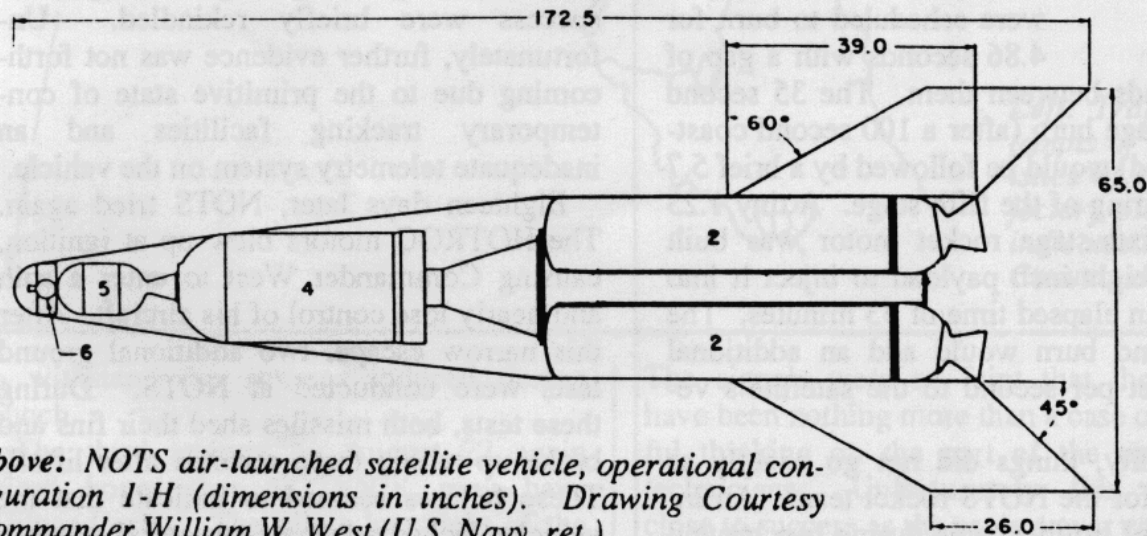
NOTS project

- First air-launched satellite attempt, off California coast
- Six tries, no confirmed successes
- 2 types of payload: radiation diagnostics for Argus artificial radiation belts, and infrared scanner instrument. 1 kg satellite!
- Five stage vehicle very unreliable
- Details did not emerge until 1990s



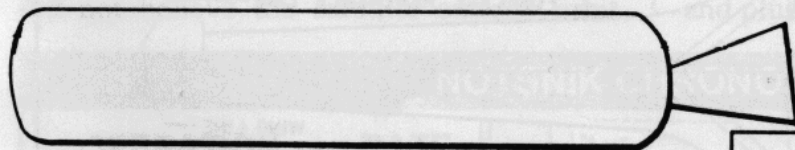
EVENT	TIME, SEC.	\angle °	ALTITUDE THOUS. FT.	RANGE, MI.	VEL. FT./SEC.
LEAVE FROM AIRCRAFT	0	30.0	80.0		574
FIRE STAGE 2	3.0	44.9	92.4		3,332
BEGIN COAST	7.3	40.9	98.8		2,534
FIRE STAGE 3	19.9	34.6	99.3		6,638
BEGIN COAST	24.7	32.9	80.9		5034
FIRE STAGE 4	82.7	2.99	280.7	10"	18,802
BEGIN COAST	160.7	3.4	282.3	175"	16,799
FIRE STAGE 5	163.7	41	283.0	182"	27,701
BEGIN COAST	173.7	1.36	284.6		20,282
FIRE STAGE 6	3200.0	0	7,938.0	12,100	21,980

Left: Trajectory map of the NOTS air-launched satellite attempts of 1958. Top: Planned trajectory and orbit characteristics of the NOTS satellites. Above: Optimized ascent trajectory plot for NOTS aerial satellite launch attempts (stage 1 indicates the launch aircraft). All Drawings and Data Courtesy Commander William W. West (U.S. Navy, ret.).



Above: NOTS air-launched satellite vehicle, operational configuration 1-H (dimensions in inches). Drawing Courtesy Commander William W. West (U.S. Navy, ret.).

Below: Specifications of the five solid propellant stages employed in the NOTS air-launched rocket (stage 1 is the launch aircraft). Data Courtesy Commander William W. West (U.S. Navy, ret.)



HOTROC

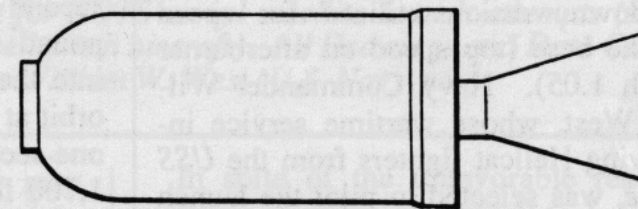
2nd and 3rd Stage

LENGTH	71.	IN.
DIAMETER	11.65	IN.
TOTAL WEIGHT	360	LB
PROPELLANT WEIGHT	300	LB
OPERATING PRESSURE	900	PSI
BURNING TIME	4.86	SEC
THRUST	14,200	LB
SPECIFIC IMPULSE	230	LB-SEC/LB
TOTAL IMPULSE	69,000	LB-SEC
MOTOR PERFORMANCE INDEX	192	

SPHERICAL 6th STAGE

LENGTH	5.5	IN.
DIAMETER	3.0	IN.
TOTAL WEIGHT	1.25	LB
PROPELLANT WEIGHT	0.7	LB
OPERATING PRESSURE	1,500	PSI
BURNING TIME	1.0	SEC
THRUST	172	LB
SPECIFIC IMPULSE	245	LB-SEC/LB
TOTAL IMPULSE	172	LB-SEC
MOTOR PERFORMANCE INDEX	138	

Top: Live NOTS rocket positioned beneath left wing of Skyray launch aircraft at NOTS airstrip in Inyokern, California.



ABL X241-4TH STAGE

LENGTH	58.2	
DIAMETER	18.0	IN(NOM)
TOTAL WEIGHT	432	LB
PROPELLANT WEIGHT	376	LB
OPERATING PRESSURE	200	PSI
BURNING TIME	36	SEC
THRUST	2720	LB
SPECIFIC IMPULSE	260.1	LB-SEC/LB
TOTAL IMPULSE	97,930	LB-SEC
MOTOR PERFORMANCE INDEX	225	

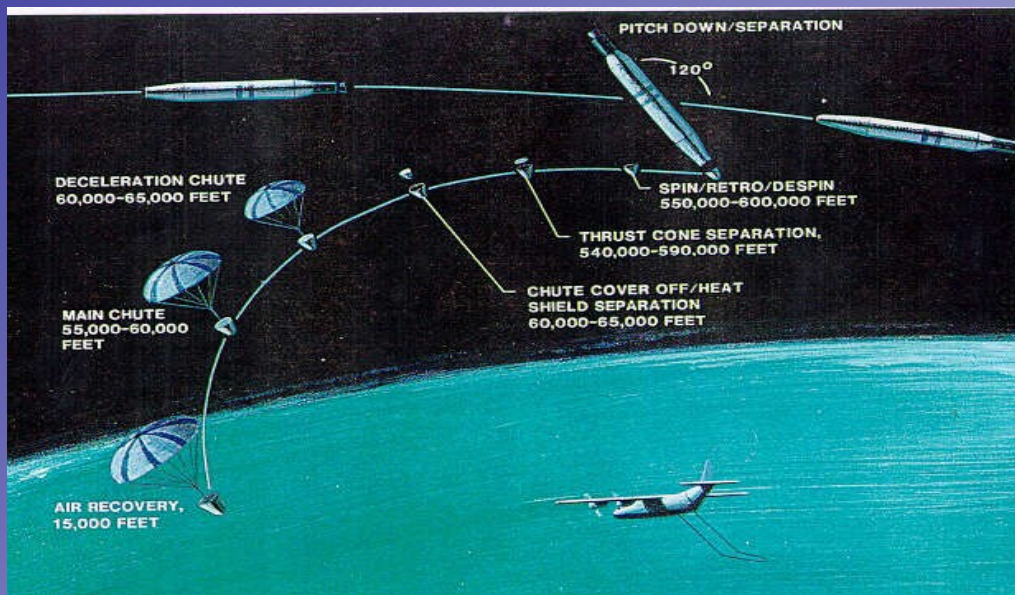


EXTRUDED 5th STAGE

LENGTH	186	IN.
DIAMETER	8.0	IN.
TOTAL WEIGHT	329	LB
PROPELLANT WEIGHT	269	LB
OPERATING PRESSURE	500.	LB
BURNING TIME	5.7	SEC
THRUST	1155	LB
SPECIFIC IMPULSE	245	LB-SEC/LB
TOTAL IMPULSE	6590	LB-SEC
MOTOR PERFORMANCE INDEX	200	

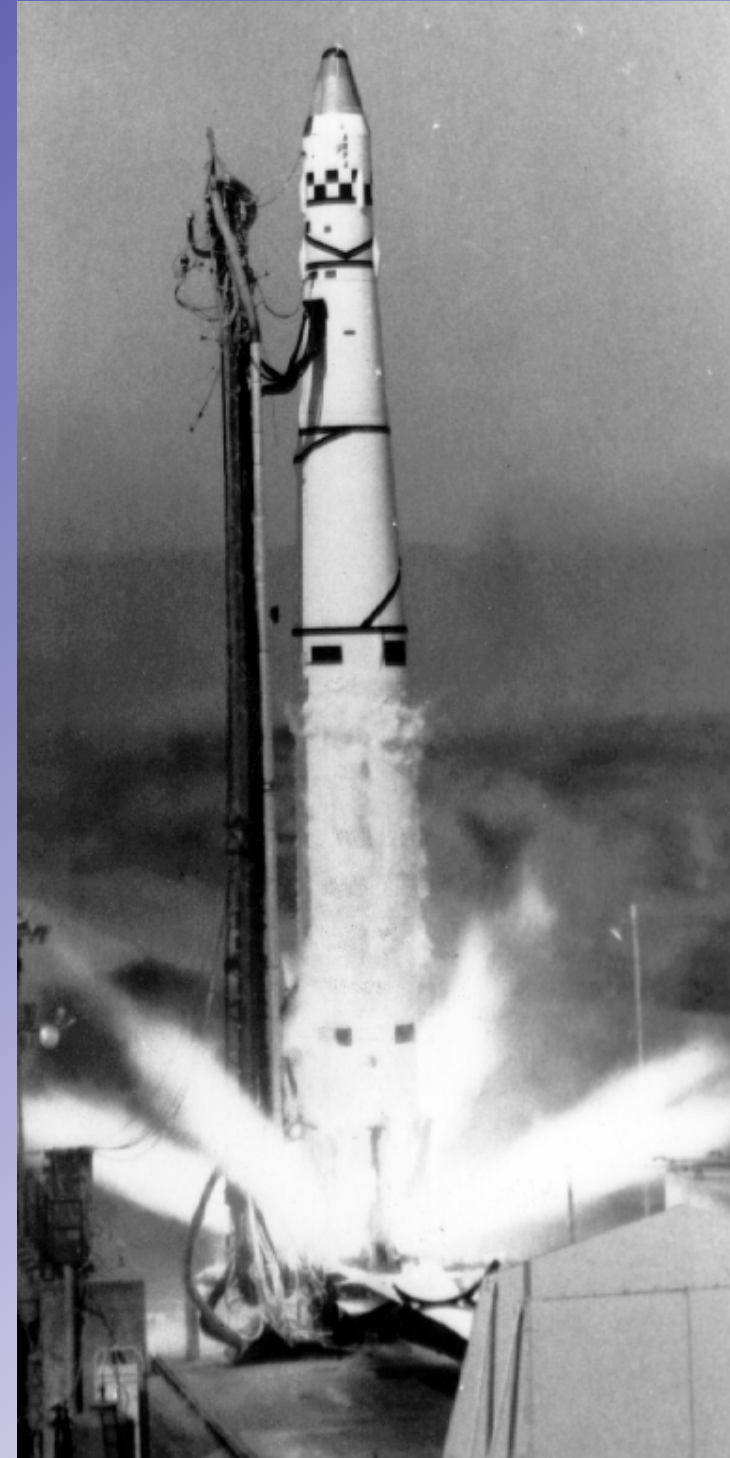
CORONA/Discoverer

- First polar orbiter (D-1, Feb 59 (?))
- First 3-axis stabilized satellite (D-2, Apr 59)
- First recoverable satellite (D-13, Aug 1960)
- First spy satellite images (D-14, Sep 1960)
- NRO formed 1961

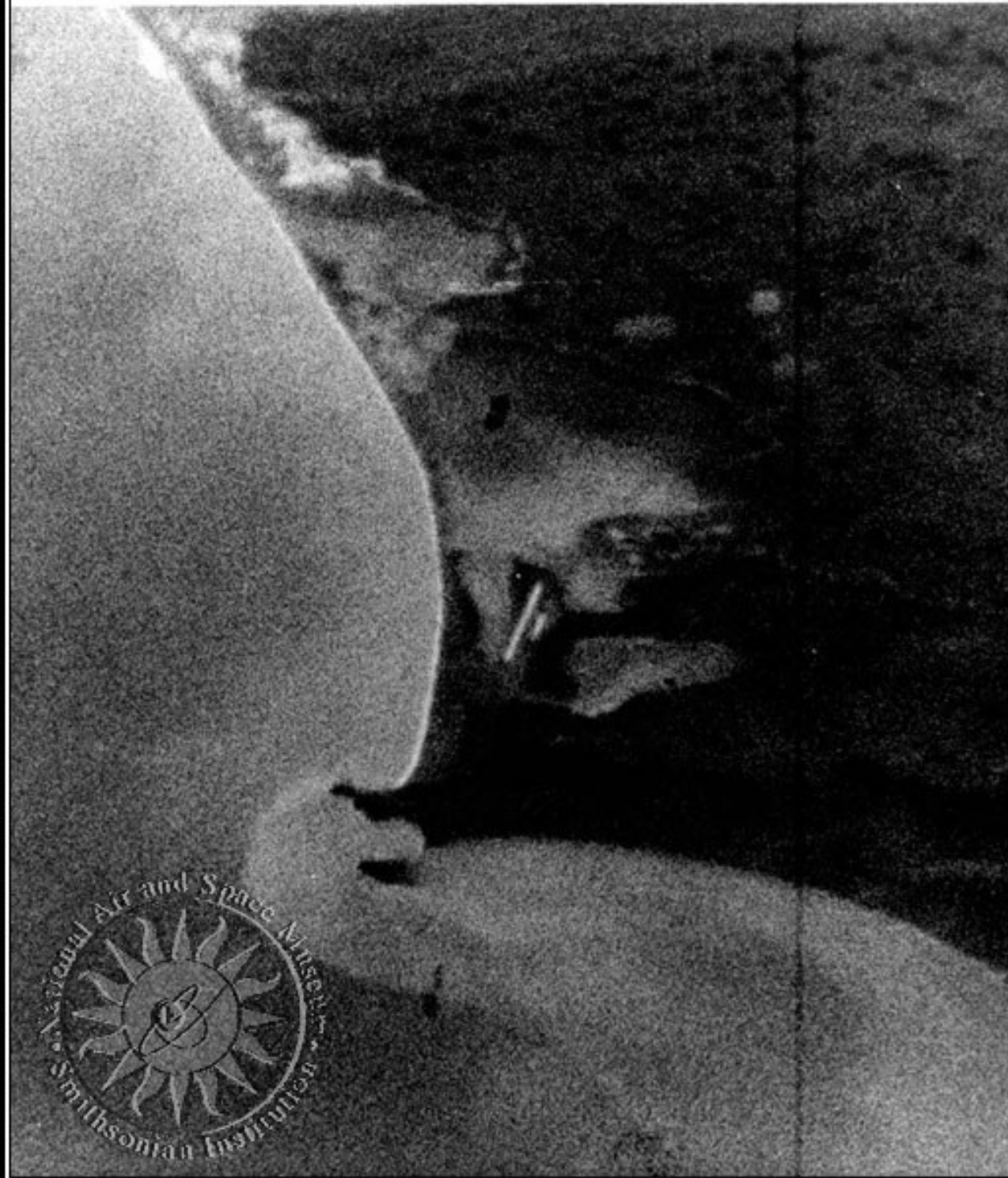


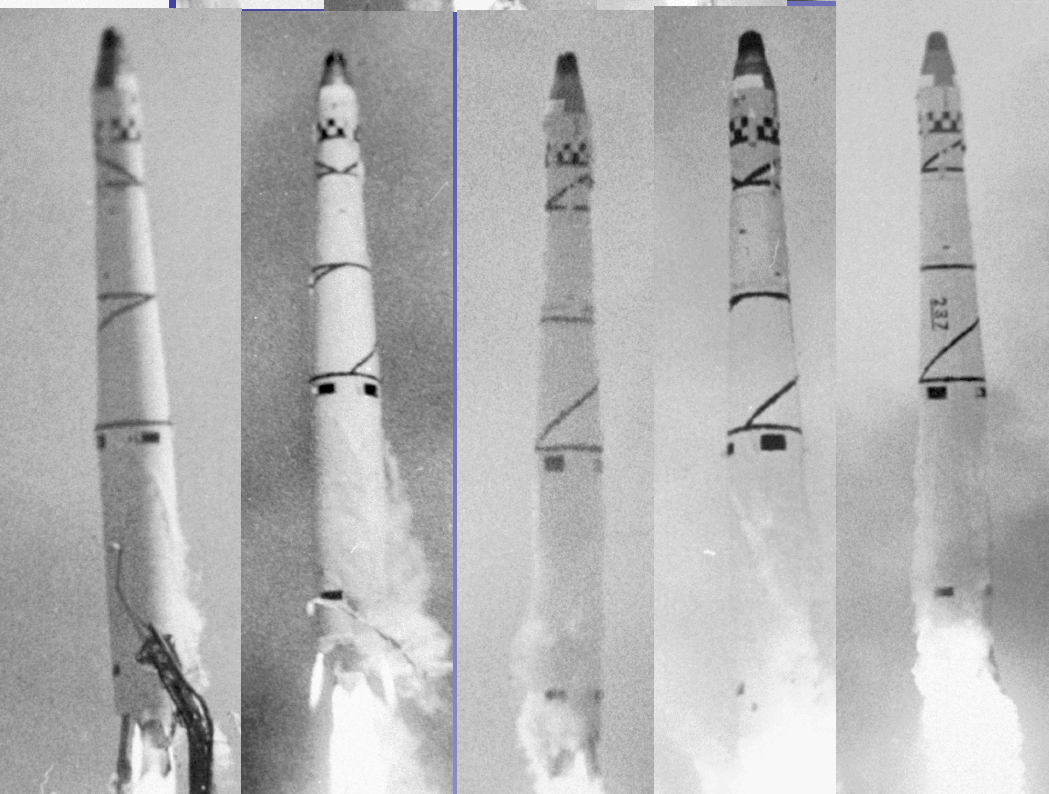
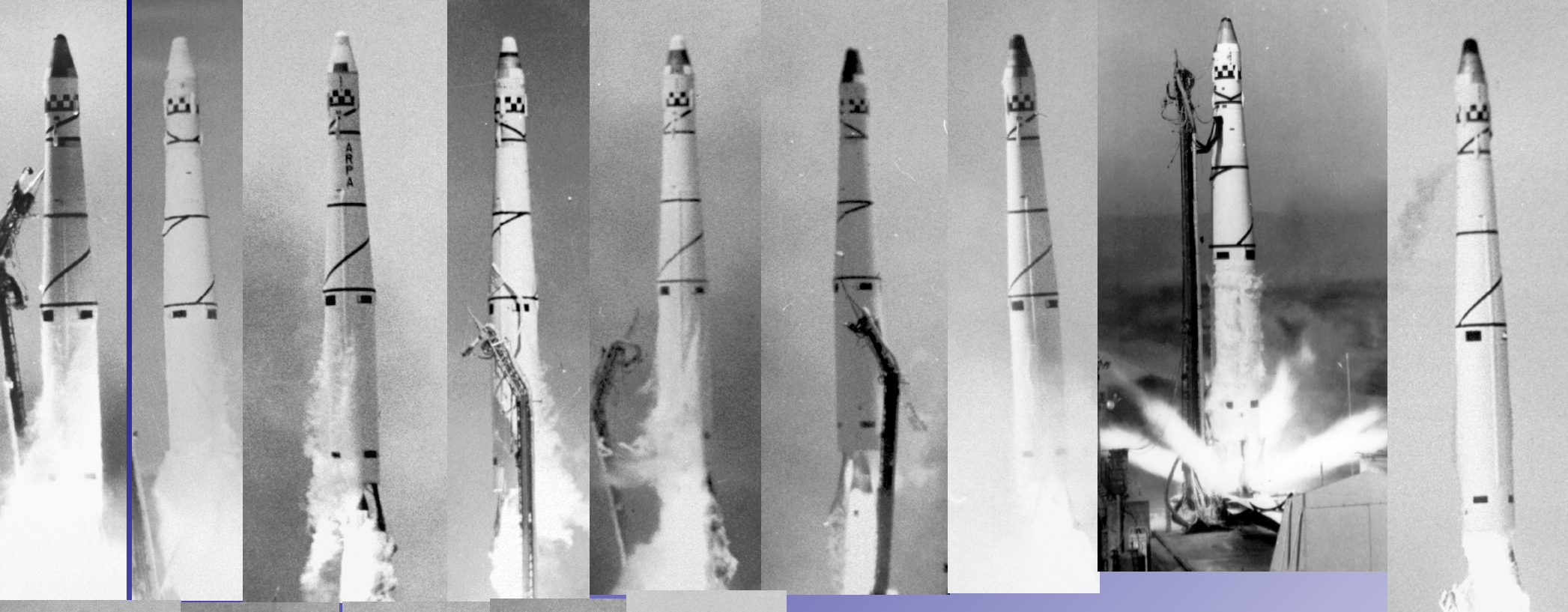
CORONA

- Discoverer 2 capsule down 1/2 orbit off - Spitzbergen (see “Ice Station Zebra”!)
- Discoverer 4 was first to carry camera - but perigee was 2 km :-(
- Discoverer 5 fired retro wrong way, high orbit
- Exploding spin rockets, failing power supply, parachute failure, launch failures...
- Discoverer 13 (no camera payload) recovered from sea
- Discoverer 14 mid-air catch, pictures of USSR airbases

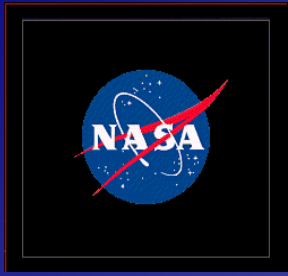


Soviet Airfield (first image), 18 August 1960





- 14 launches in only 18 months until 1st full success
- The benefits of priority funding and failure-tolerant political support!



NASA is formed



- NACA Langley lab (Virginia) - Balloon satellites, Scout, Mercury, and aeronautical research
- NACA Ames lab (San Francisco) - aeronautical research
- NACA Lewis lab (Cleveland) - engines
- NRL Vanguard group - moves to new “Beltsville Space Center”, later called Goddard
- Army ABMA group (Huntsville) - becomes NASA-Marshall in 1960
- Army contract with JPL goes to NASA
- Small group at Canaveral later becomes KSC; Houston develops in mid-1960s

Space launches Oct 1957- May 1961

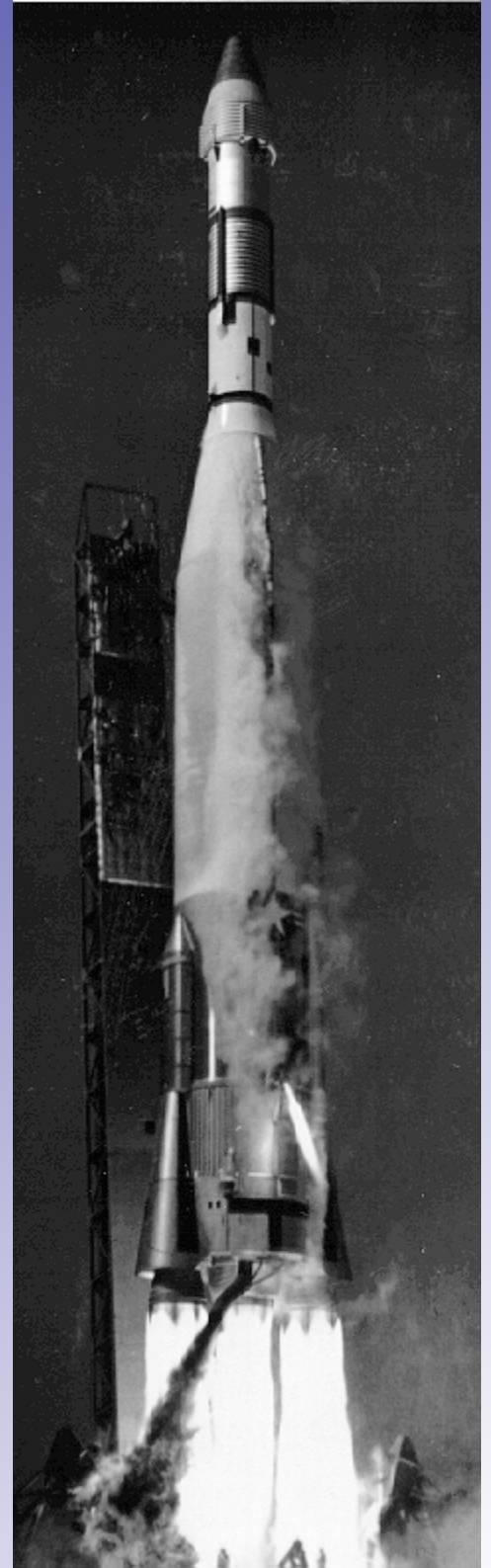
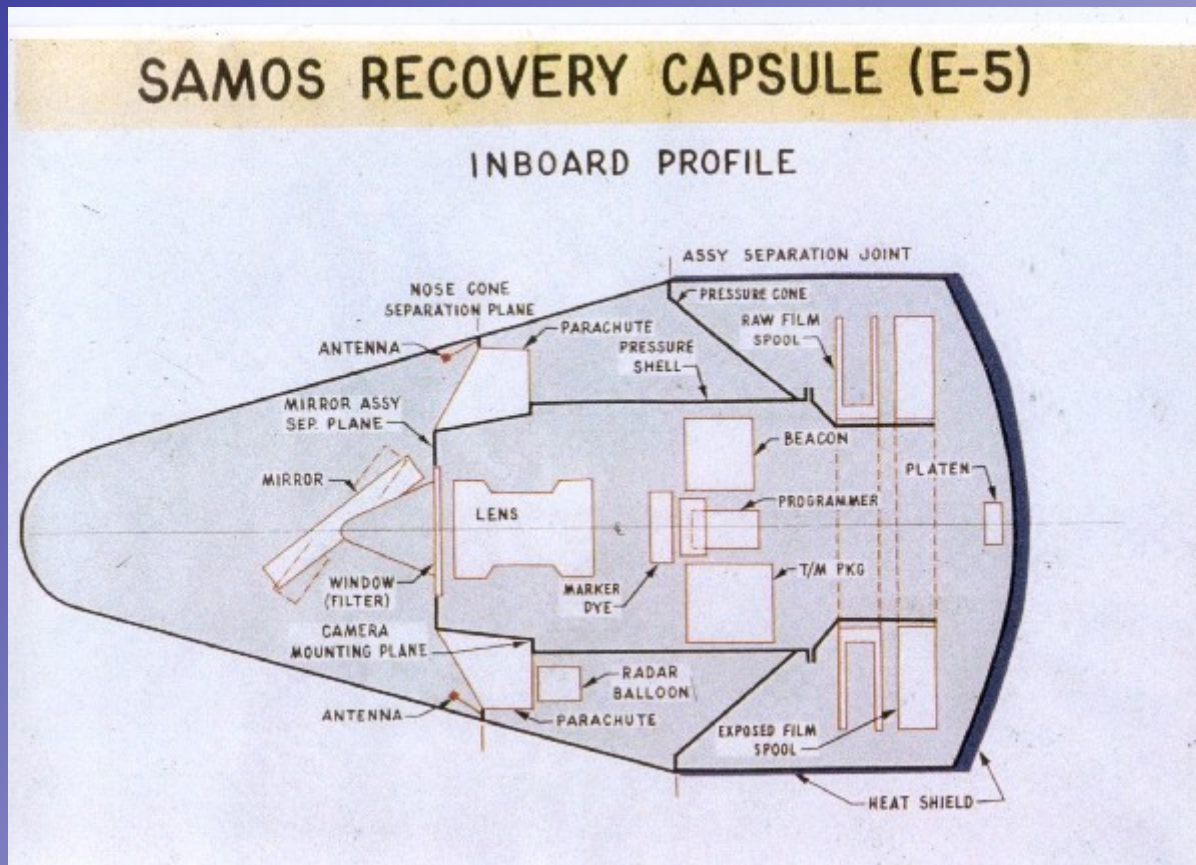
- Total orbital attempts 109
- USSR attempts 14 out of 25 successful (+1 failed in parking orbit) which is 56 percent (or 60 percent)
- US attempts 41 of 84 successful, or 49 percent
- Marginal case: USSR Apr 1960 moon launch counted, had 200000 km apogee, better than Pioneer 1 and 3
- If these probes are excluded rates are 52 percent to 46 percent
- Within root-n Poisson standard deviation, both countries had 50 percent success rate
- Note the small number of early USSR launches despite large number of “firsts”

Space launches Oct 1957- May 1961

- Von Braun's Jupiter/Juno: 50 percent (16 launches)
- Douglas Thor: 65 percent (40 launches)
- NASA-Langley Scout: 50 percent (2 launches)
- Convair Atlas: 33 percent (9 launches)
- Rosen's Vanguard: 27 percent (11 launches)
- NOTS: 0 percent (6 launches)
- Yet within 5 years success rates rose to 92-97 percent
- Similar improvement for USSR rockets

New horizons 1961-1962

- SAMOS E-5: the pressurized spy satellite boondoggle
- Somewhere under the Yukon snows...

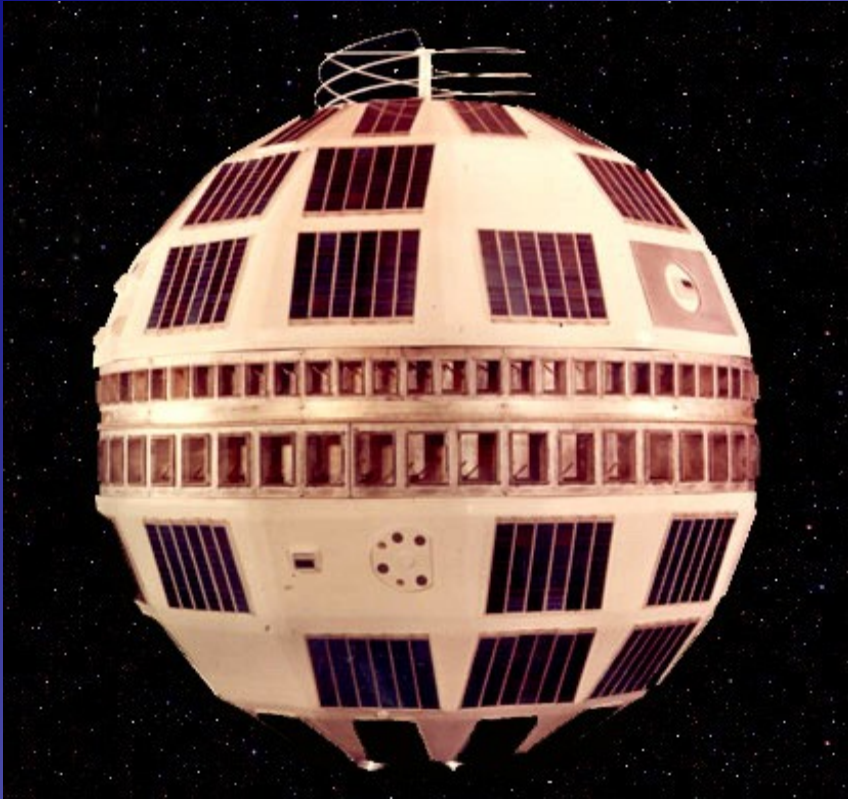


New horizons 1961-1962

- P35, the NRO's weather satellite
- Launched by Scout rockets
- Parallel to NASA Tiros weather program
- Cloud cover monitor for CORONA
- Later supported Vietnam ops, led to modern DMSP Air Force weather sats



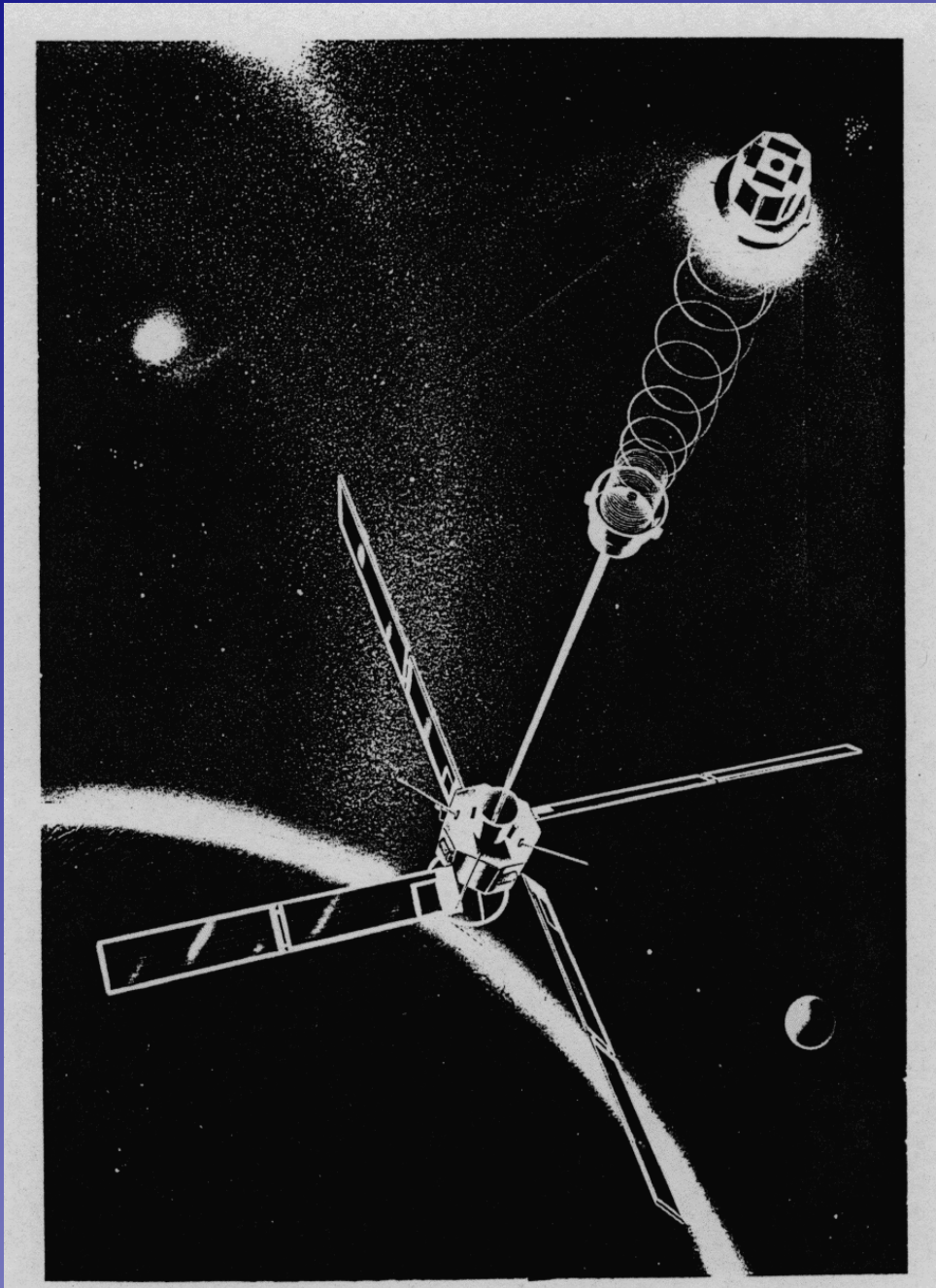
New horizons 1961-1962



- Telstar - first true (real-time, active) communications satellite (1962, medium height orbit)
- First GEO satellite was Syncom 3 in Aug 1964, followed by Early Bird and ATS-1 in 1965-66

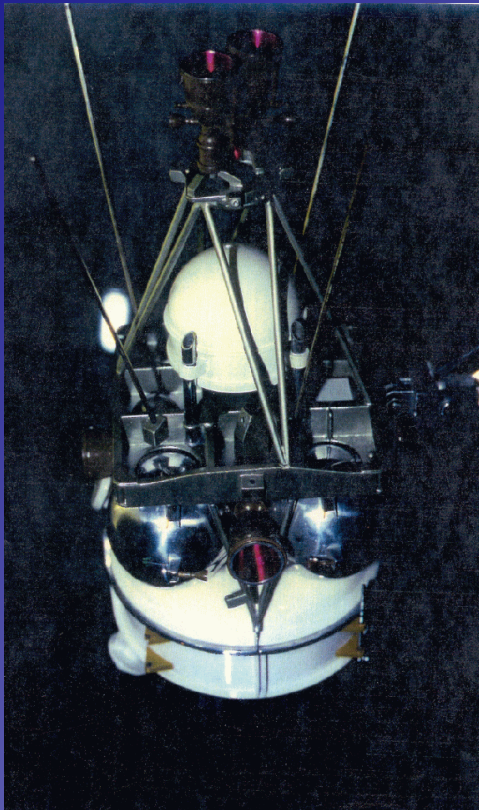


New horizons 1963

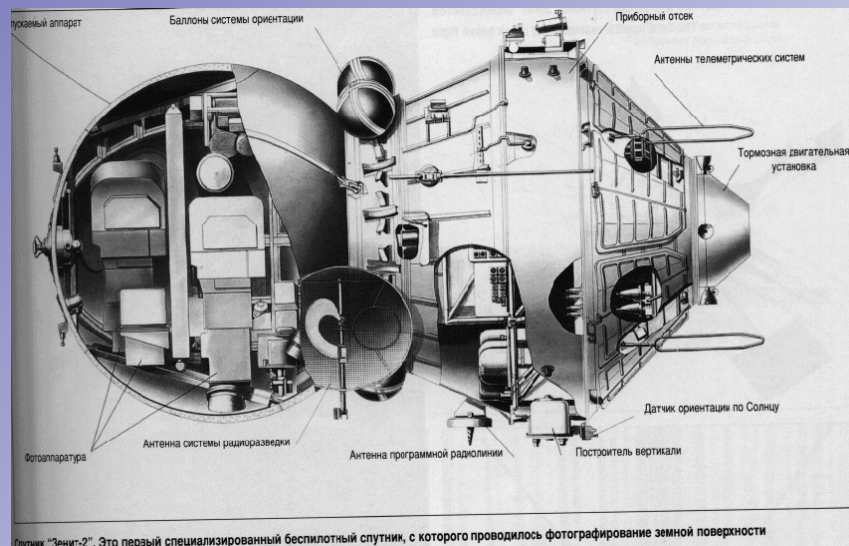


- Transit 5A-3: first gravity gradient satellite, June 1963 (5A-1 failed in Dec 1962)
- Prototype for Doppler navigation system
- Applied Physics Lab (Maryland) for US Navy
- 30-meter boom

New horizons 1962-3



- Chelomei antisatellite weapon prototype Polyot-1, Nov 1963
- Claimed as first maneuvering satellite (arguable)
- Zenit-2 spy satellite (Dec 61 launch failure, Apr 62 success)



New horizons 1962

- Ariel (UK owned, UK-built instruments, US-built satellite)
- Alouette (Canadian built and owned, US launched)
- The satellite age begins to reach beyond the superpowers

