Bigger and Hotter Rockets and their Consequences

By William Mook

Moore's law in electronics proceeds from an analysis of the fundamental cost drivers in integrated circuit production, which boils down to cost per feature, or cost per circuit in terms of wafer real estate. Are there fundamental laws that drive the cost of interplanetary travel? The answer to that question is yes. This "Mook's" law boils down to cost of momentum, or cost of lift, in terms of delta vee. As the cost of lift falls, the mass flow rate over a given delta vee for a given number of dollars per year increases.

Since the delta vee for minimum energy transport around the solar system from Earth's surface is well-defined, the cost of material flows between worlds can be predicted for a given momentum cost. The volume and cost of these flows can then be estimated and from that a development plan evolved.

Over the first 20 years of spacefaring development (1946 to 1966) we saw the following development of chemical rocket technology;

1946 V2	1.0 T payload	12.5 T takeoff weight	5.76 km/sec	239 Isp	$3.0 billion
1956 R7	2.0 T payload	267.0 T takeoff weight	9.20 km/sec	306 Isp	$4.5 billion
1966 S5	45.0 T payload	2,800 T takeoff weight	10.85 km/sec	420 Isp	$6.5 billion

The rockets get bigger and hotter to reduce the cost of momentum. We go through the following development arc:

(1) Small suborbital payloads;
(2) Moderate orbital payloads;
(3) Large cislunar payloads.

Space-Based Paradigm Shifts for Earth

Since all people on Earth with minor differences bear the same relationship to the cosmos, any cosmic development off-world affects all those on Earth's surface equally. So, it is natural that the result of rocket development results in global paradigm shifts as well as the creation of global delivery of products and services.

Our development arc in bigger hotter rockets therefore resulted in the following global paradigm shifts:

(1) ICBM	→	Mutual assured destruction	→	Uneasy global peace
(2) Sputnik	→	Communications satellites	→	Global communications/sensing
(3) Apollo	→	Photo of whole Earth from Moon	→	Environmental movement

Still-born, and under-reported, were what can only be termed the "spiritual" insights of early explorers, which is rather amazing among a group of hard-boiled scientists, engineers, and military jocks. Reports of Samadhi were common. For example, Edgar

Mitchell founded the Noetic Institute to promote his insights to the world. Al Bean became an artist to communicate his vision. Charles Duke became a minister.

It should not be surprising to find that sending large numbers of people deep into space across the solar system results in insights that we could call religious in nature.

In November 1963, the first meeting the newly installed President Johnson had at the White House was with Robert McNamara. He reviewed the proposed NASA budget for 1964. That budget year saw a shift as America's bold adventure in space became a manned moon program. This resulted in the abandonment of nuclear propulsion efforts as well larger, hotter chemical rockets. A focus on the moon was accentuated and the development of bases and other capabilities beyond the moon landing were abandoned.

What could we expect if development had not been curtailed in 1964 budget year? Well, NERVA and ROVER programs might have borne fruit. Also, nuclear pulse programs like the first Orion program might also have borne fruit, as Freeman Dyson wrote in a Science article in 1964.

Nuclear Pulse propulsion would certainly meet the larger and hotter engine criterion.

These advanced propulsion programs carried out in the 1960s would likely have cost less than the space shuttle and would definitely have given us industrial access to the solar system. So, we add a fourth step to our growth curve, one for 1976 at a cost of $10.1 billion.

(4) Orion → Nuclear Pulse → Disarmament & Solar Power Satellites

The ability to beam laser and maser energy from space, generated by tapping into abundant sunlight far from Earth, naturally leads to ion rockets and beamed thermal rockets to expand upon the high temperature technologies explored first with nuclear technologies. At that size and temperature, the cost of materials retrieved from the solar system falls to price points associated with ocean travel and the mass-flow rates increase accordingly. Thus, propulsion more than anything else leads to off-world mining. This begins with mining rare Earths and low volumes of materials that are exceptionally rare here and moves toward more common materials as prices fall. Large power satellites reduce the cost of energy. As the cost of energy declines, the cost of extracting materials from regolith generally rather than ores becomes cost effective. Materials may also then be extracted from waste material cost-efficiently, reducing the mass flows needed to sustain high standards of living. This was recognized by NASA scientists back in the 1970s, who originally outlined this development cycle and coined the term Demandite.

So, along with an increased sensitivity toward our environment due to the photo of the whole Earth from space, there is an increased capability to live lightly on the Earth and make greater use of off-world resources to preserve our environment.

The ability to beam power in copious quantities to both stationary and moving targets from space not only provides a means to defend against missiles, but also a means to provide low-cost laser propulsion generally, allowing individuals access at lower cost to the same development arc afforded weapons in the 1940s and satellites in the 1950s. The personal ballistic vehicle will have arrived along with on-demand flight to any point on Earth in a matter of minutes and eventually the development of orbital residences. These are expected to cost $15.2 billion for ballistic transport around Earth and $22.8 billion to develop the infrastructure to permit an orbital capability on demand for everyone.

(5) Laser propulsion → Low cost ballistic transport → Global transport network
(6) Low cost laser → Low cost space access → Global real-estate in space

Expanding capabilities in space mean that power satellites operating inside the orbit of Mercury can be developed. These satellites are capable of beaming energy across the solar system, providing another radical reduction in the cost of energy and an increase in the amounts of energy humanity handles. This leads naturally to missions beyond 660 Astronomical Units, using laser light sails and a new innovation that recycles photons called the photonic thruster. This last innovation permits the efficient use of laser light sails at very low speeds, yet maintains relatively high efficiency. At 660 AU the gravity field of the Sun itself is used to survey the 100 stars within 32 light years of Earth in advance of missions to these stars. These observatories are also the places where energy is beamed to the star and focused by the sun's gravity very efficiently, permitting long distance light sail and even photonic thruster operations. This leads to the final step in the next decade of development, star travel, for $34.2 billion.

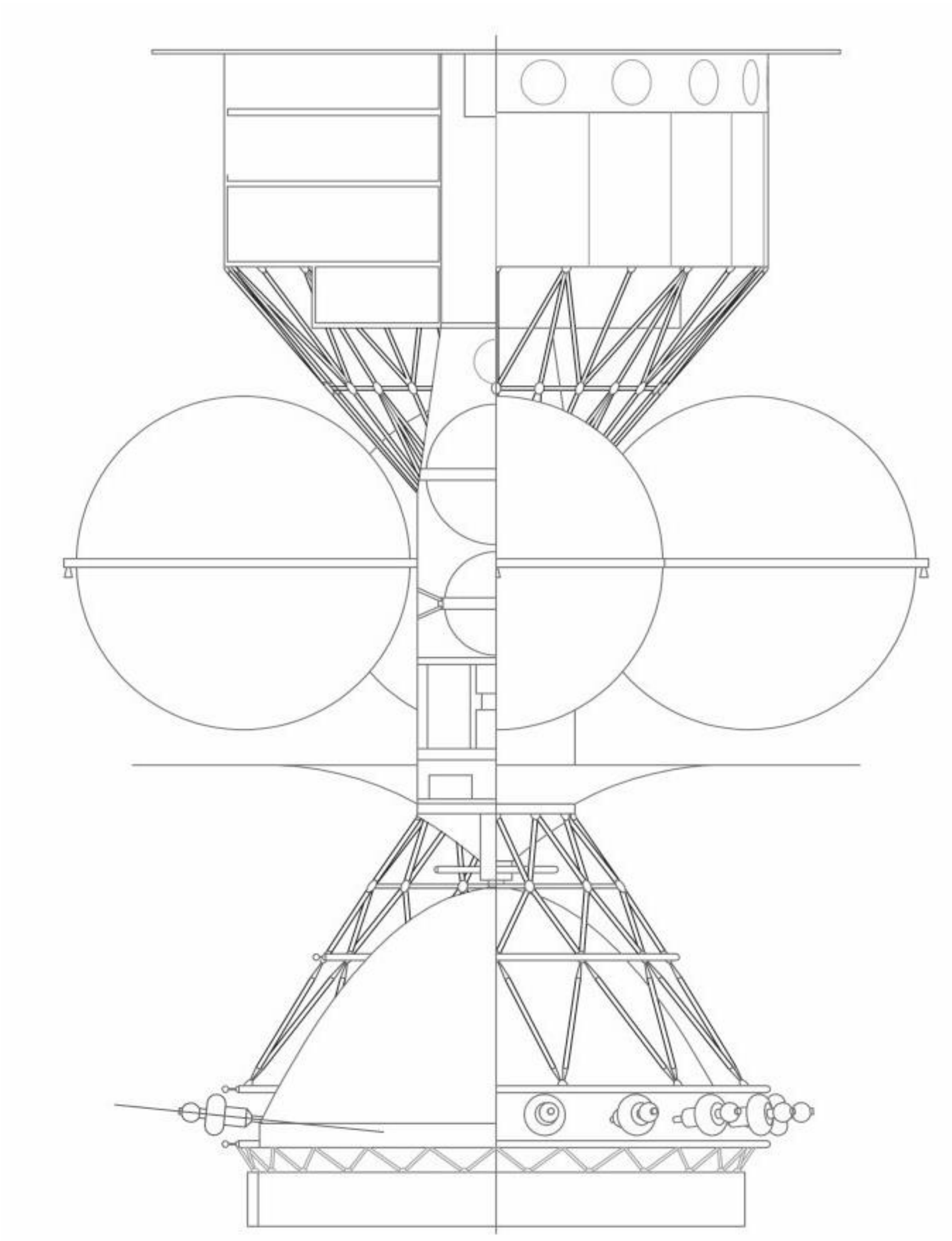
(7) Ultra-low-cost laser → Interstellar travel → Diaspora

These developments are not merely for exploration and development or to satisfy idle curiosity. These developments, like ICBMs, communications satellites, and the environmental movement, will affect all people everywhere very directly in the same way.

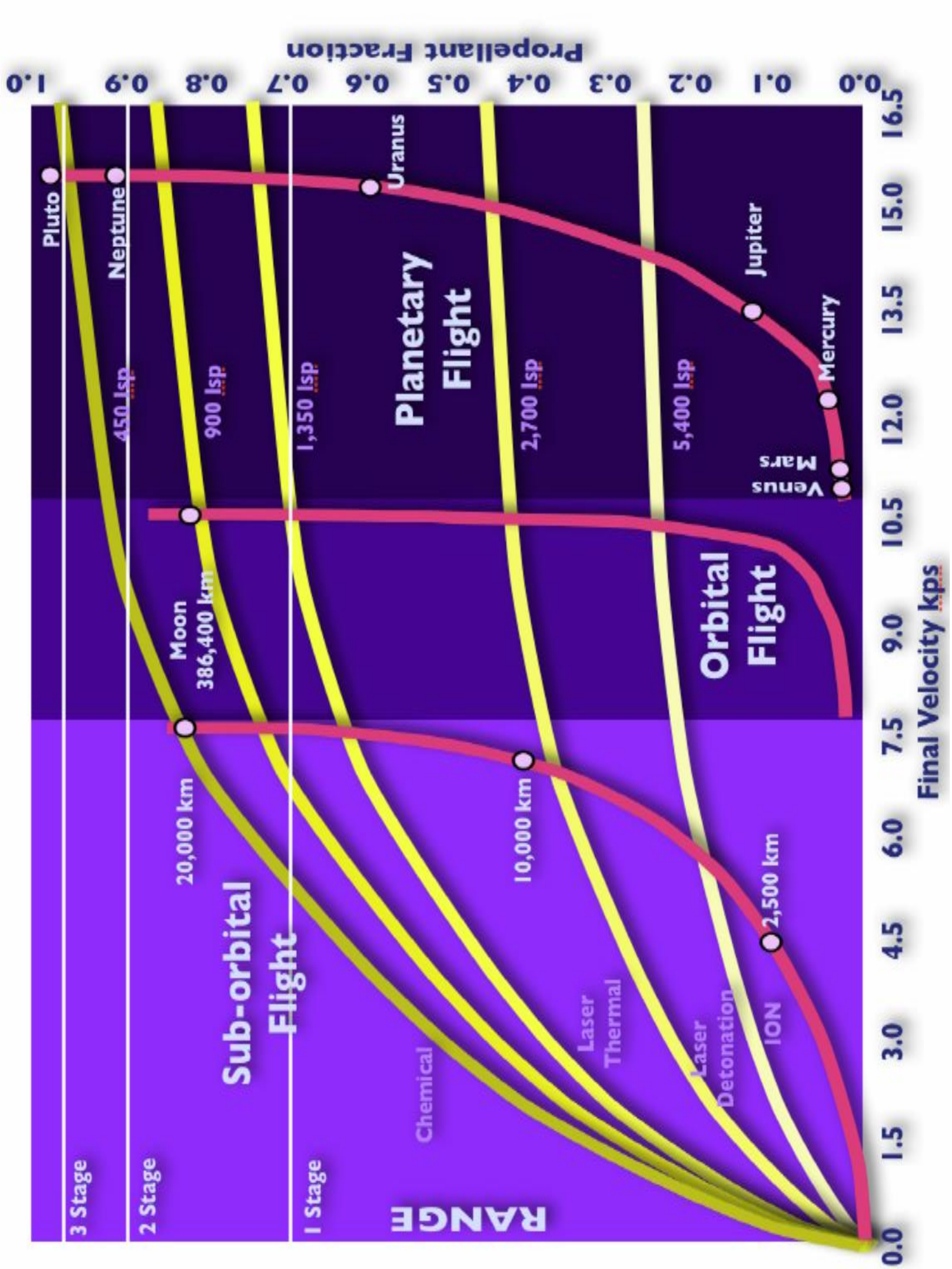
The heavens will open to humanity. While population rises, the numbers of people on any one planet will fall, leading to a condition in 100 years' time where people are exceedingly wealthy, powerful, and knowledgeable, but very rarely seen at any one spot. The Earth will return to a nature preserve and a resource of native life to charge our artificial biospheres. Our space homes will set sail across interplanetary space and then interstellar space. Beyond that, we will again be found in small, far-ranging tribes across the stars.

I have outlined this in more detail at www.youtube.com/watch?v=d0e2FJmXujA. I welcome informed feedback. I outline what we can do today to transform life on Earth using space technology before the year 2040.

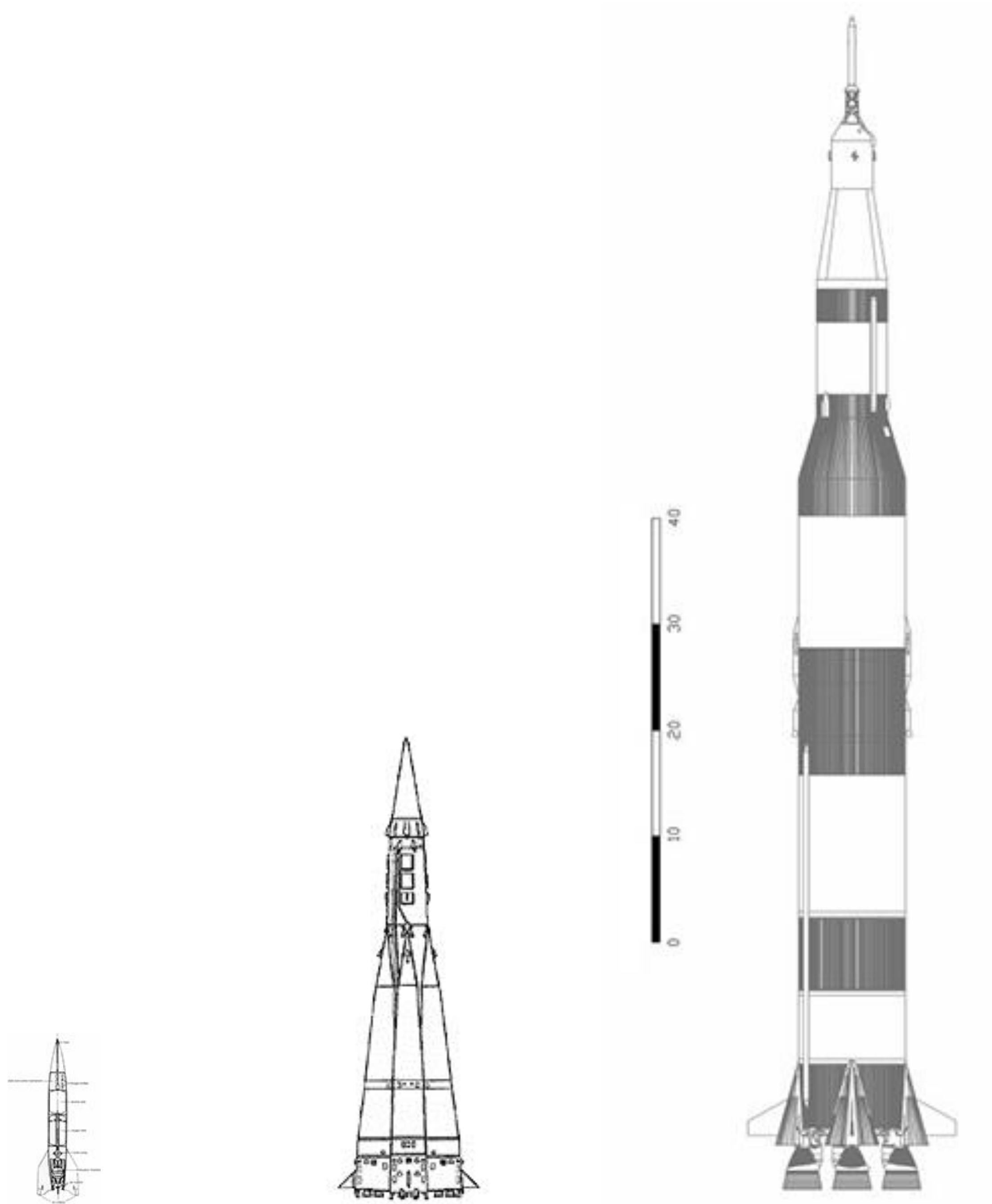
The Fourth Generation of Rockets
Nuclear Pulse



Daedalus/Orion
Nuclear Pulse Rocket
1970
$10.1 billion
10,000 t
6,000 t (interplanetary)


Propellant Fraction
Final Velocity kps
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
15.0
16.5
RANGE
1 Stage
2 Stage
3 Stage
Sub-orbital Flight
Orbital Flight
Planetary Flight
Chemical
Laser Thermal
Laser Detonation
ION
450 Isp
900 Isp
1,350 Isp
2,700 Isp
5,400 Isp
2,500 km
10,000 km
20,000 km
Moon 386,400 km
Venus
Mars
Mercury
Jupiter
Uranus
Neptune
Pluto

The First Three Generations of Rockets



V-2	R-7	Saturn V
Sub-Orbital Rocket	Orbital Rocket	Moon Rocket
1940	1950	1960
$3.0 billion	$4.5 billion	$6.8 billion
12.5 t	380.0 t	3,039 t
4.2 t	6.5 t	45 t (lunar)

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About William Mook, PE: Bill Mook has innovative science and technology ideas for more subjects than anyone you have met. Those subjects range from the rocket history he covers in this article to sustained industrial futures in Space. He approaches his subjects from a mix of engineering knowledge through financial analysis and imbeds them in philosophical rationale as a foundation to support his statement *"The heavens will open to humanity."* He has had management and fiscal responsibility on Fortune 500 R&D teams and provided analytic work for the White House during both the Clinton and Bush Administrations. He holds patents for ground-breaking product developments. He is a member of the Board of Editors for *The Journal of Space Philosophy*.

Editors' Postscript: We encourage readers to find the published work of Bill Mook on the Internet. His analyses of Earth and Space energy and Space resources are solid evidence within *the Law of Space Abundance* that the Kepler Space Institute formulated in 2009. *Bob Krone and Gordon Arthur*.