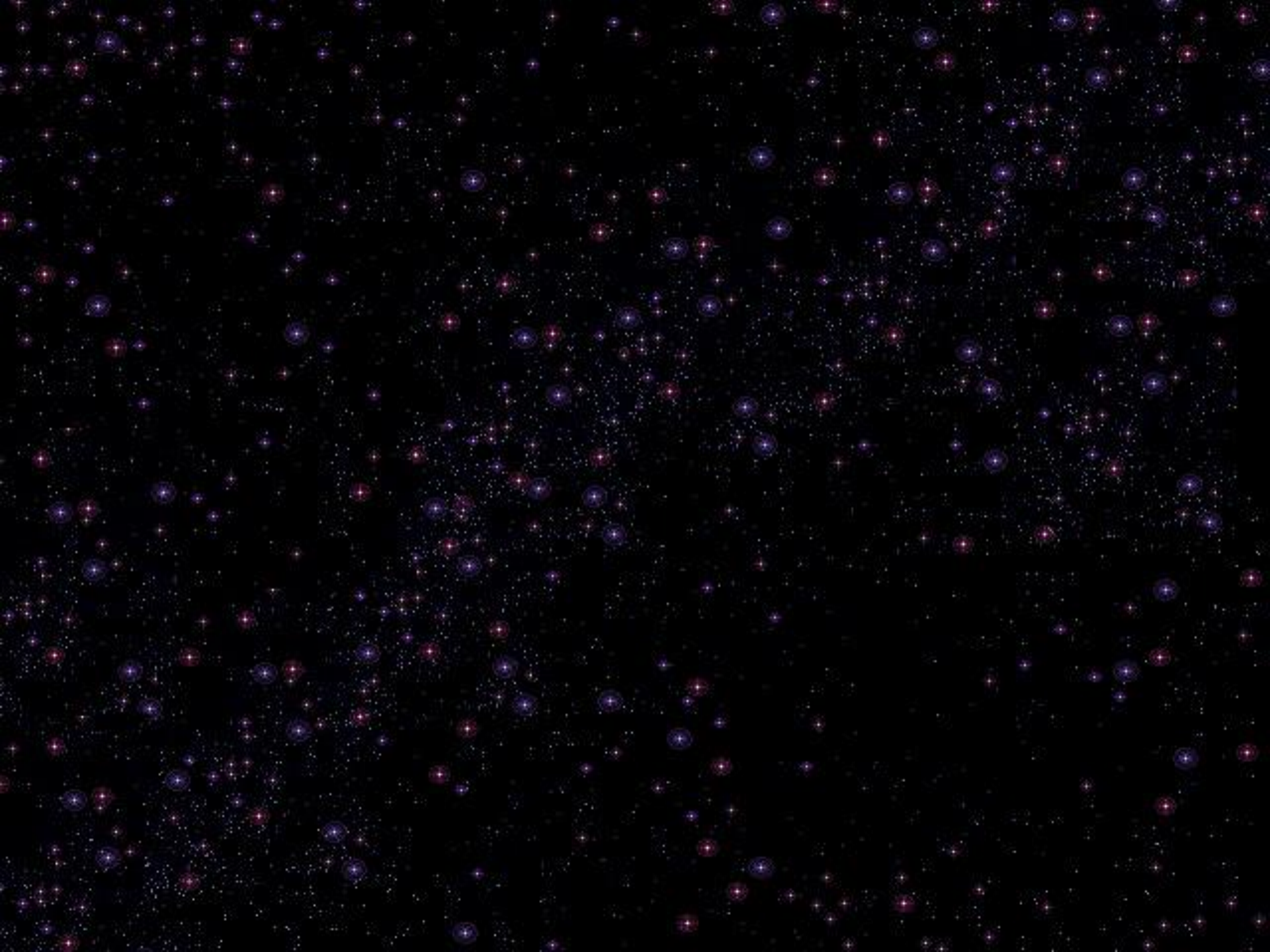
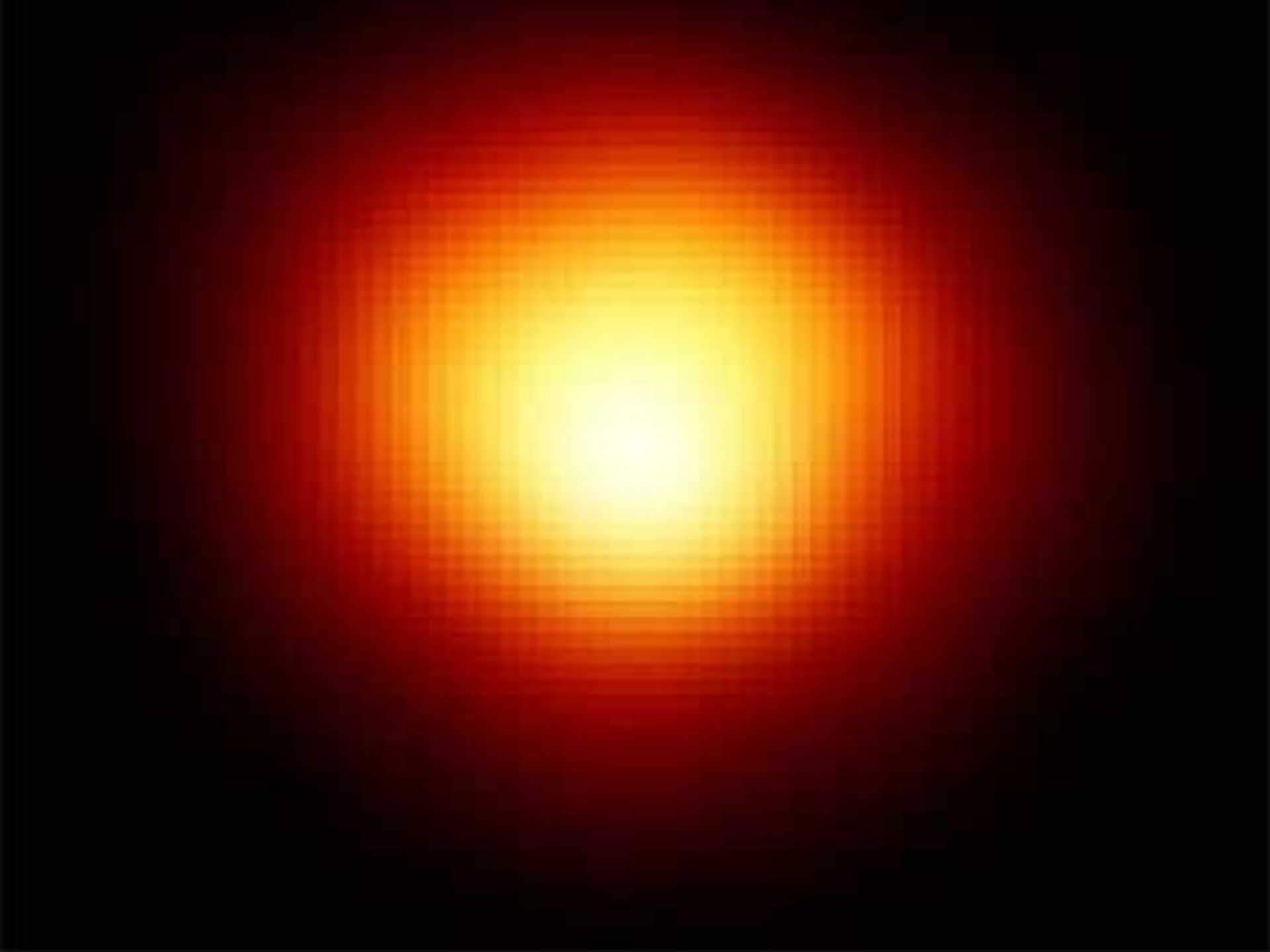


APOPHIS

APOPHIS




3'27'04

Getting to Mars: Comparison of Proposed Launch Vehicle Effects

- G Launch Profiles –
- Vibration Profiles –
- Additional Considerations -

VIBRATION

Human Vibration Limits:

- Max allowable by ISO 2631 is 0.8Gs
- Typically this will be at 5-50 Hz

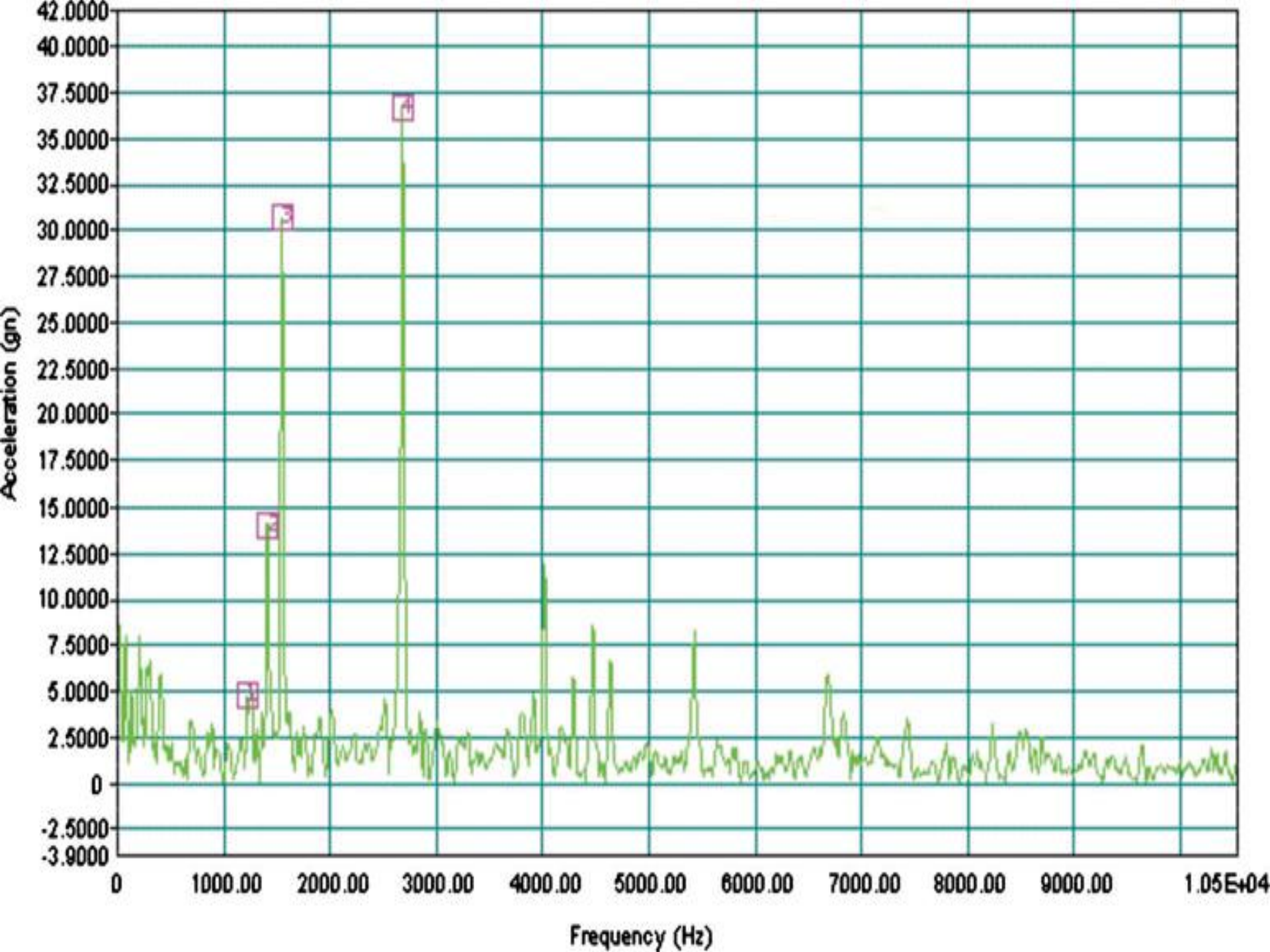
Vibration Physiologic Effects

- Within ISO guidelines (whole body):
- Headaches
- Muscle spasm- minor strain

- Over exposure:
- TBI
- Vascular intimal injury
- Clinical Musculoskeletal injury
- Renal epithelial injury

Common Comparison Sources:

- Roller Coaster: 0.1-0.8 G vibration (5-200 Hz) superimposed upon a primary background of minimal minus to plus 6 G sinusoidal/periodic accelerations. (wooden has most vibration)
- Jack Hammer: 5- 25 M/s/s (0.5- 2.7 G)
- Subway: 60 VdB (0.01 – 0.3 G)


42.0000
40.0000
37.5000
35.0000
32.5000
30.0000
27.5000
25.0000
22.5000
20.0000
17.5000
15.0000
12.5000
10.0000
7.5000
5.0000
2.5000
0
-2.5000
-3.9000
Acceleration (gn)
0
1000.00
2000.00
3000.00
4000.00
5000.00
6000.00
7000.00
8000.00
9000.00
1.05E+04
Frequency (Hz)

Falcon 9 Launch

FALCON 9

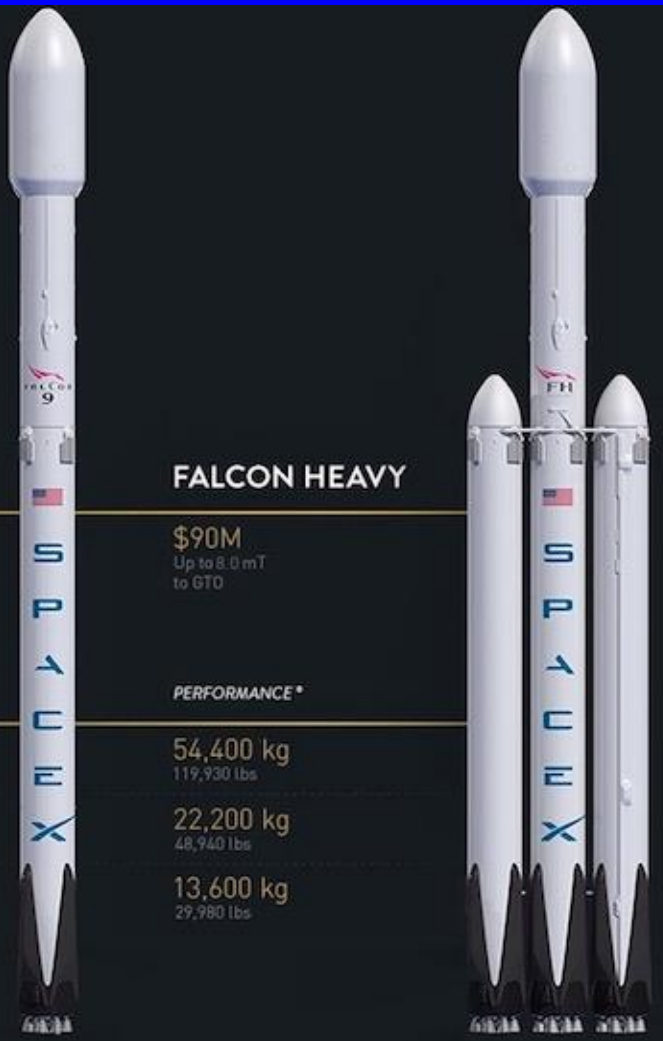
- G load profile of 6 – 8.5 Gs along the longitudinal axis.
- Acoustic vibratory profile of 0.5-0.9 Gs spread across a 5-100 Hz spectrum with lateral vibrations of 0.5-0.6 Hz
- Duration of 500 seconds

Falcon 9 vs Heavy

CAPABILITIES & SERVICES

SpaceX offers open and fixed pricing for its Falcon 9 and Falcon Heavy launch services. Modest discounts are available, for contractually committed, multi-launch purchases. SpaceX can also offer crew transportation services to commercial customers seeking to transport astronauts to alternate LEO destinations.

PRICE	FALCON 9	FALCON HEAVY
STANDARD PAYMENT PLAN (2018 LAUNCH)	$62M Up to 5.5 mT to GTO	$90M Up to 8.0 mT to GTO
DESTINATION	***PERFORMANCE****	***PERFORMANCE****
LOW EARTH ORBIT (LEO)	22,800 kg 50,265 lbs	54,400 kg 119,930 lbs
GEOSYNCHRONOUS TRANSFER ORBIT (GTO)	8,300 kg 18,300 lbs	22,200 kg 48,940 lbs
PAYLOAD TO MARS	4,020 kg 8,860 lbs	13,600 kg 29,980 lbs



*Performance represents max capability on fully expendable vehicle

Inclination: LEO = 28.5°, GTO = 27°

Falcon Heavy – Engine View

Flacon Heavy – Launch (sim)

Vibration Terms

F = force

m = mass

a = acceleration

D = peak to peak displacement

Δf = bandwidth in Hertz

V = velocity

g^2/Hz = acceleration density

f = frequency in Hertz (Hz)

g = the acceleration of gravity

g_{rms} = the rms value of acceleration in units of gravity

Vibration Equations

Sinusoidal Vibration

Velocity, Acceleration and Displacement Relationships					
English			Metric		
$V = \pi fD$			$V = \pi fD$		
$V = 61.48 \times g \div f$	D = inches peak to peak		$V = 1.56 \times g \div f$	D = meters peak to peak	
$g = 0.0511\ f^2\ D$	V = inches per second		$g = 2.013\ f^2\ D$	V = meters per second	
$g = 0.016266Vf$	f = frequency in Hertz (Hz)		$g = 0.641\ Vf$	f = frequency in Hertz (Hz)	
$a = 0.102Df^2$	$g = 386.1$ inches/second^2		$a = 4.026Df^2$	$g = 9.80665$ meters/second^2	
$D = 0.3183 \times V \div f$	a= inches/second^2		$D = 0.3183 \times V \div f$	a = meters/second^2	
$D = 19.57 \times g \div f^2$			$D = 0.4968 \times g \div f^2$		

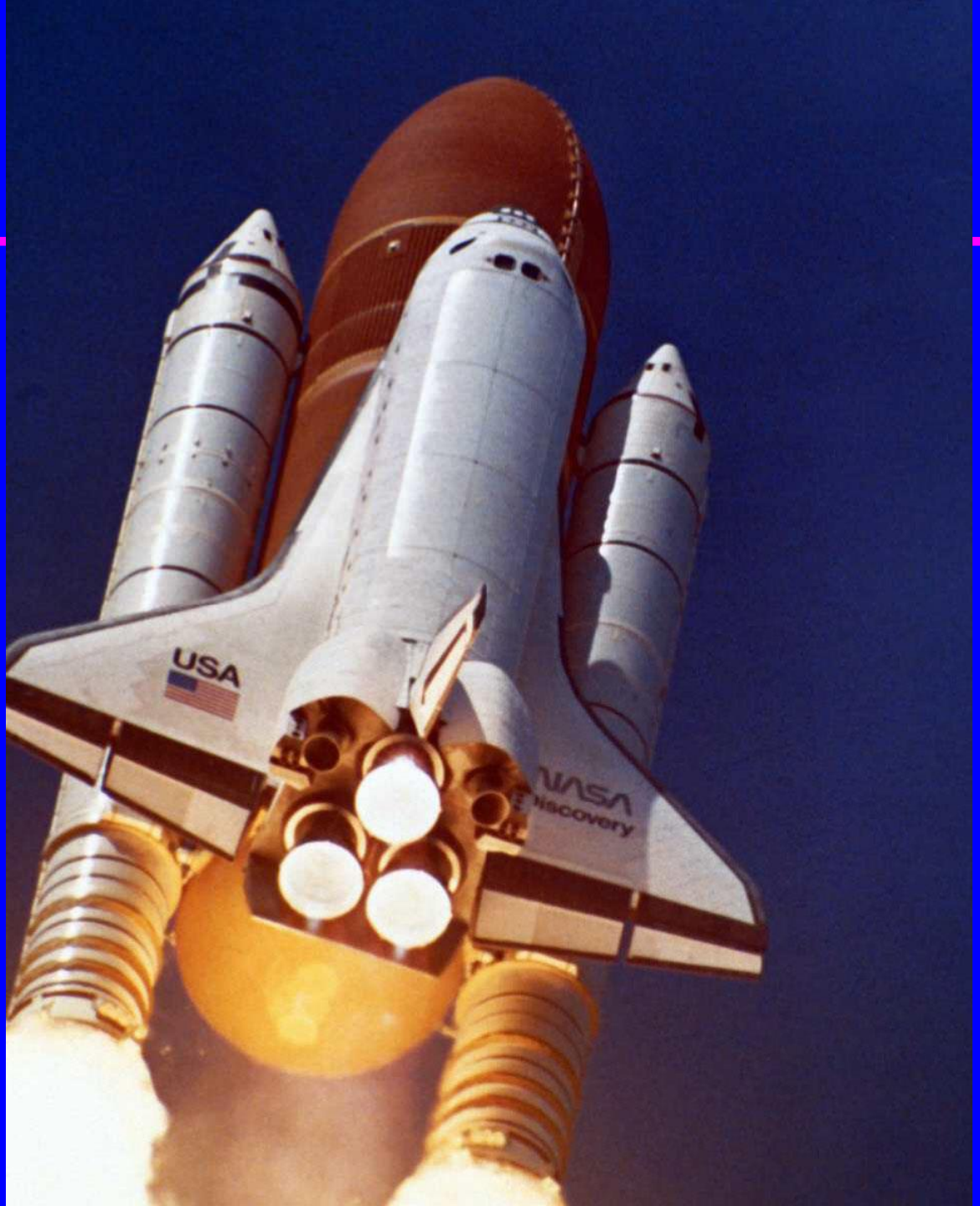
Constants for True Sine Waves	
rms value = 0.707 X peak value	peak value = 1.414 X rms value
rms value = 1.11 average value	peak value = 1.57 X average value
average value = 0.637 X peak value	peak to peak = 2 X peak value
average value = 0.90 X rms value	crest factor = peak value ÷ rms value

Random Vibration

Acceleration, Acceleration Density and Displacement Relationships (For a flat or white noise spectrum)
$g_{rms} = SQR\ [\Delta f\ (g^2/Hz)]$
$g^2/Hz = (D \div 42.8)^2 \times f^3$
$D = 42.8\ [SQR\ (g^2/Hz \div f^3)]$

Falcon HeavyLaunchProfile(est)

- Estimated Maximum Not Greater than :
- 10 G (longitudinal)
- 1.2 G (vibratory) in the critical 5-50 Hz range.
- Dampening techniques could lower vibration to 0.8


USA
NASA
Discovery

RS – 25 SLS – stage 1

- 3 G axial load
- Vibration 0.5-0.7 Gs across a 5-100 Hz spectrum
- Duration of 450 seconds.

SLS stage 2 - JX-2 engines

- Unknown profile
- Prior attempts resulted in vibration profile outside the limits of human tolerance
- Human limits for vibration: are 0.8Gs at 5-50 Hz which is the most sensitive area of the range.

RS-25 with Falcon 9

- Although Unknown and Untested,
- Would likely fall within acceptable limits, given the separate components meet the physiological requirements , and these would be employed in series.

- However the engineering and logistics of such a combination have not been explored.

Additional Concerns:

- Payload limitations and requirements
- Radiation exposure
- Zero G countermeasures

Payload Limitations:

- Falcon Heavy – 28 tons to escape
- Saturn V – 50 tons to escape
- SLS-1 – 45 tons to escape

Payload Requirements:

- Martian Colony – 50-100 tons to Mars
- Crew with return – 28 tons (Zubrin)
- Crew without return - 28 tons (standard)

Conclusions:

- No currently tested and available vehicle meets the ISO vibration requirements for human spaceflight beyond earth orbit.
- The combination of the RS25 as booster and falcon 9 as upper stage would meet the ISO standard, if logistically feasible .
- Although the currently conceived launch vehicles could theoretically accomplish a round trip to Mars, these logistics require further development.

PHYSIOLOGIC CONCERNS

RADIATION

MAGNETIC FIELD

TEMPERATURE

VIBRATION

NOISE

- OTHER (Standard Microgravity Effects /Chemical exposures, Psychological, Time in transit, Time Dilation)

RADIATION

Galactic Cosmic Radiation : 0.5 Sv/yr.(with 15 gm/sq cm shielding)

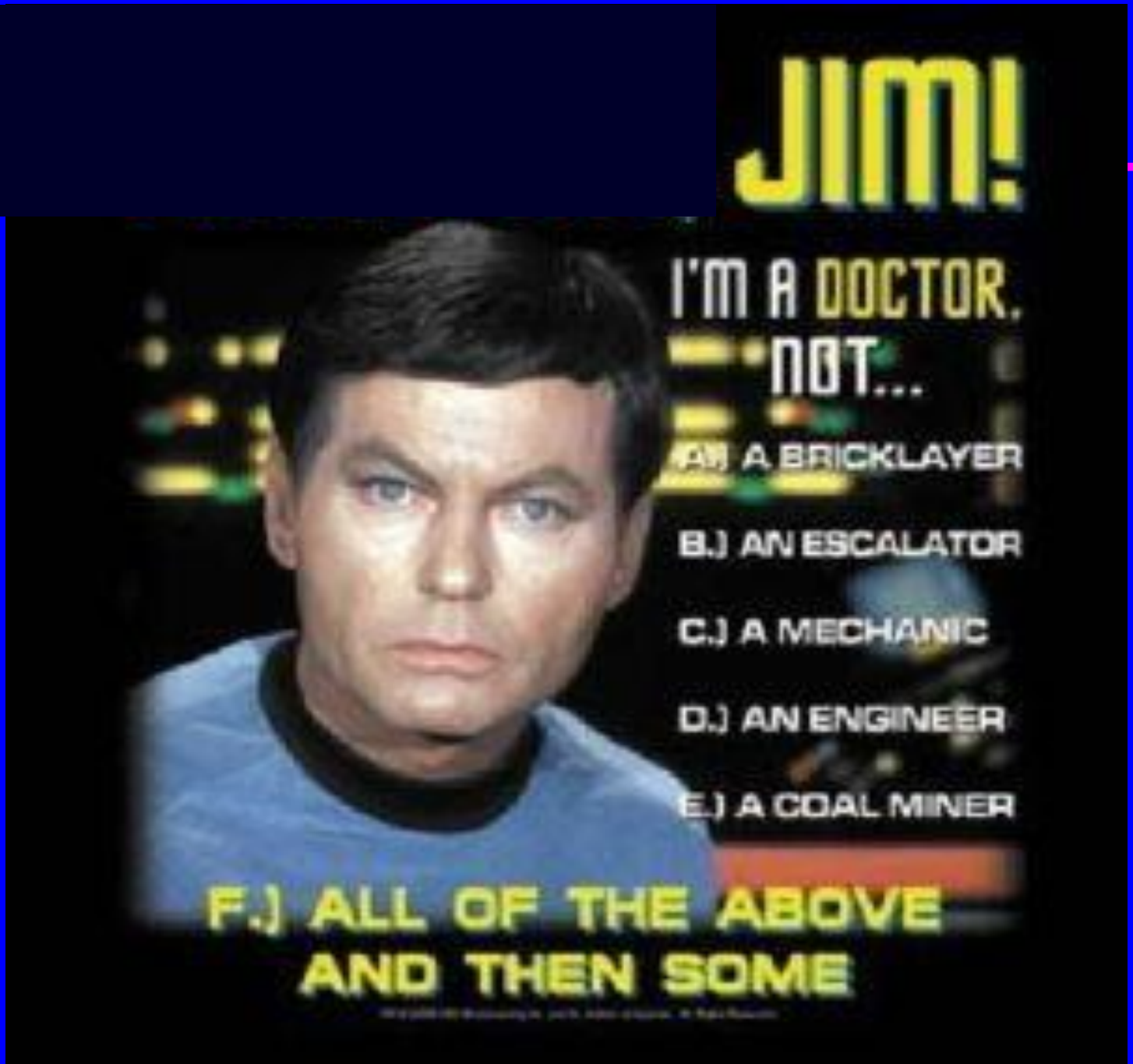
Nuclear Reactor : additional 0.1 Sv/yr.(with 10cm lead or 180 cm of water between reactor and crew)

The MagnetoPlasma Impulse engine would require a 200 MW Nuclear Reactor about 1/3 the size of a typical power plant reactor and 6 times the size of that in a nuclear submarine.

VIBRATION

VIBRATION

- Conventional : 0.56G sinusoidal peak to peak force at 15-50 Hz frequency
- (Max allowable by ISO 2631 is 0.8Gs)
- All others are substantially less:


JIM!
I'M A DOCTOR, NOT...
A.) A BRICKLAYER
B.) AN ESCALATOR
C.) A MECHANIC
D.) AN ENGINEER
E.) A COAL MINER
F.) ALL OF THE ABOVE AND THEN SOME

NOISE

- Conventional: 220 Db
- Solar Sail: <60 Db
- Others in between

TIME

- Transit Time

  Time Dilation
- Gamma = 1/ sq rt of 1- β x β
- where β = *v/c* and *v* is the relative velocity between two inertial frames.
- t’ = gamma x t.
- At 0.95 c 1 year= 3.2 years at the ref pt.

ZERO-G CORP


We're Behind You, Atlantis!

LAST FLIGHT FROM POLE

Plato's Cave


the Fire
Roadway where puppet showmen perform
Shadows cast on this wall
Prisoners
ascent to Sunlight
diffused Sunlight

FALCON 9 LAUNCH AT KSC

ORBITAL SCIENCES CORP

- TAURUS 2 Rocket CYGNUS Spacecraft

- Signed 1.9Billion $ NASA contract for 8 cargo flights to ISS
- Test Flight at Wallops Island VA in 2011

VIRGIN GALACTIC

- RICHARD BRANSON (Record Company)
- Made History with Spaceship one
- Spaceship 2 will carry 6 passengers
- Suborbital
- Launch in 2011/12 from New Mexico

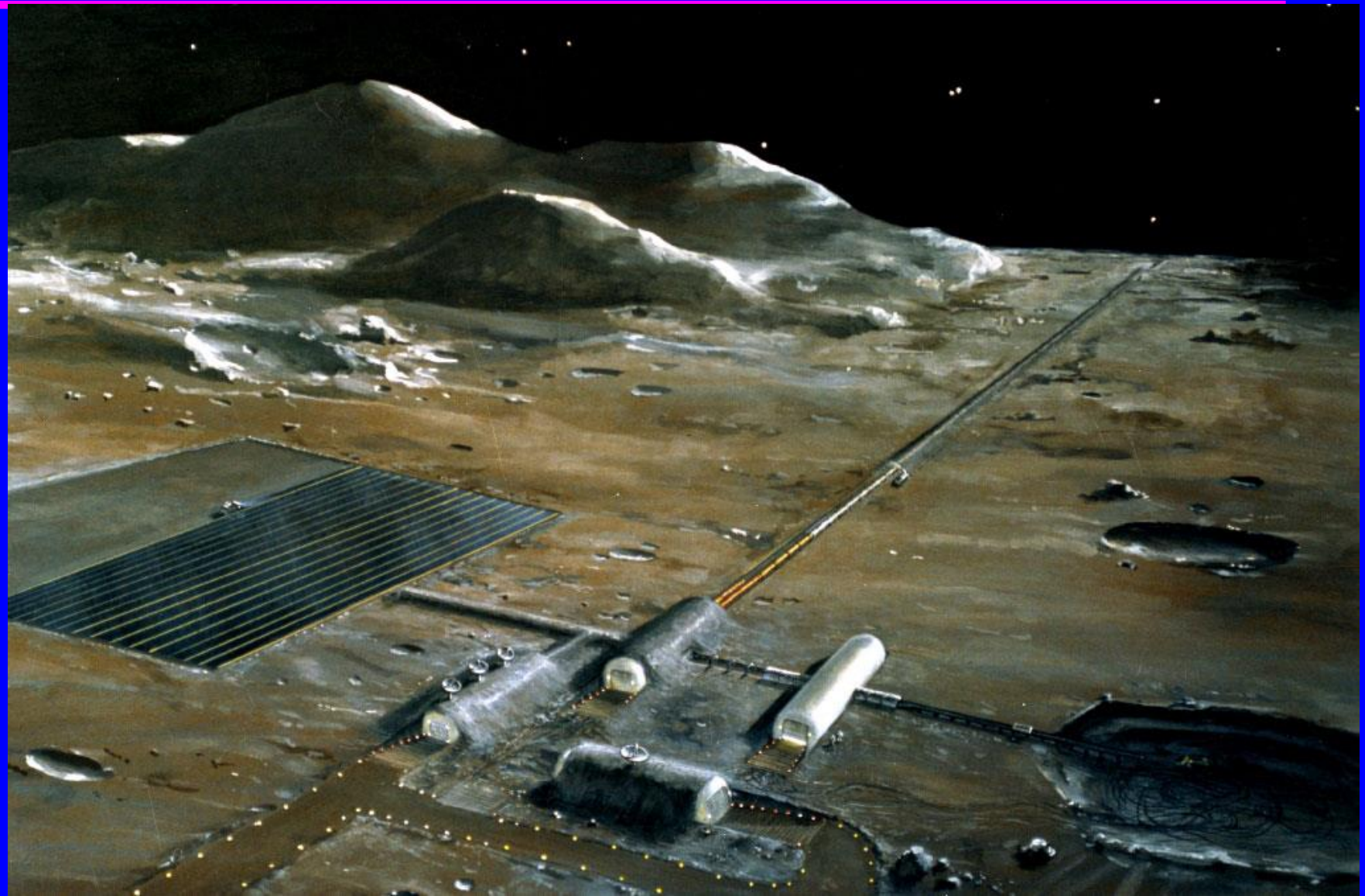
AsMA ROLE

- COMMERCIAL SPACEFLIGHT WORKING GROUP
- CREATING MEDICAL GUIDELINES FOR PILOTS AND PASSENGERS
- MEETS AT AsMA ANNUAL AND FALL MEETINGS
- MARK CAMPBELL is CHAIR mcamp@1starnet.com

THE FUTURE

- HEAVY LIFT ROCKET ENGINE
- HISTORY OFTEN IS KEY TO FUTURE
- EARLY MEDICAL INVOLVMENT IS A PRIORITY FOR MISSION SUCCESS

OCCUPATIONAL SPACE MED



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- AEROSPACE MEDICAL ASSOCIATION WEBSITE: http://www.asma.org/<http://www.asma.or