Human Spaceflight

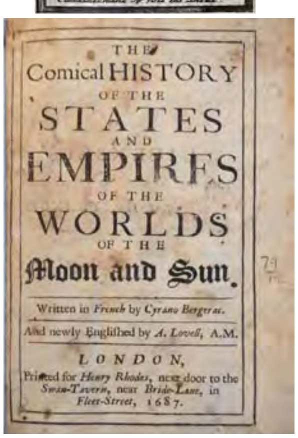
Space System Design, MAE 342, Princeton University
Robert Stengel

- Historical concepts and mis-concepts
- Manned spacecraft and space stations
- Extravehicular activity
- Physiological and metabolic issues
  - Health and space medicine
  - Radiation exposure
  - Life support systems
- Control capabilities and human error

Princeton, '38

A Voyage to the Moon

Cyrano de Bergerac (1619-1655)


THE
Comical HISTORY
OF THE
STATES
AND
EMPIRES
OF THE
WORLDS
OF THE
Moon and Sun.

Written in *French* by *Cyrano Bergerac.*
And newly Englished by *A. Lovell,* A.M.

LONDON,
Printed for *Henry Rhodes,* next door to the *Swan-Tavern,* near *Bride-Lane,* in *Fleet-Street,* 1687.

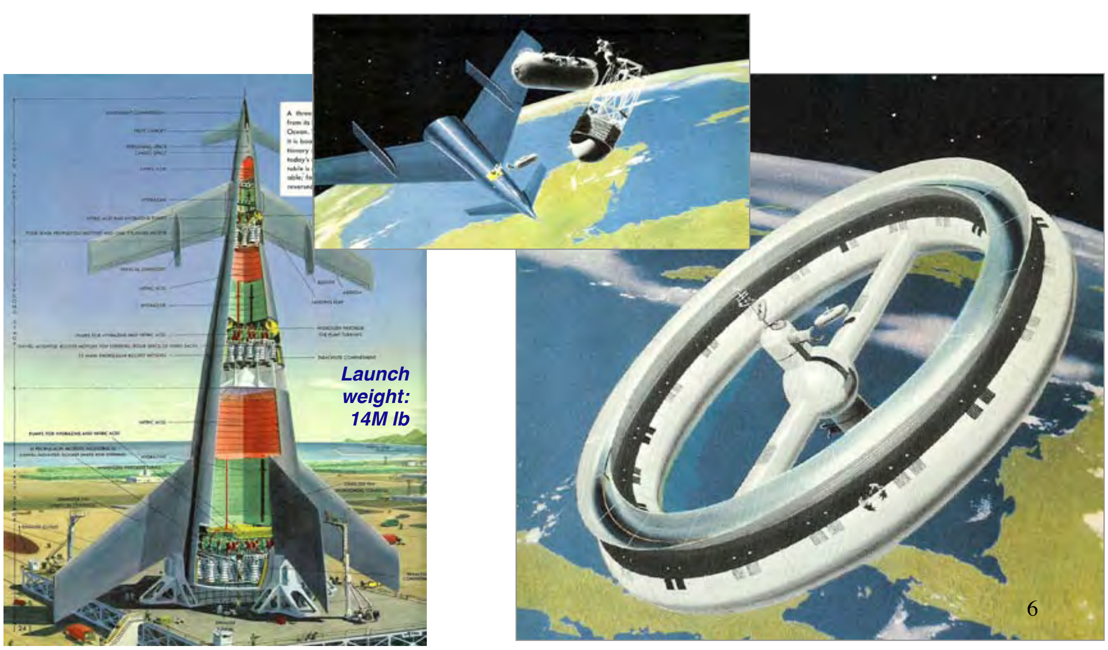
- **Hercule-Savinien Cyrano de Bergerac**
- ***"Comical History of the States and Empires of the Moon"*, written about 1649, published 1656 or 1657**
- **English translation, 1687**
- ***In Firestone Library (below & left)***

Cyrano's Voyage to the Moon and Back

5

1952 Rocket Ship/Space Station Concept

C. Ryan, W. von Braun, *et al*, *Across the Space Frontier*, *Collier's Magazine*



6

7

Why Humans in Space?

- Exploration
- Scientific discovery
- Engineering development
- Construction, maintenance, and repair
- Pilots, tourists, and tour guides

Man vs. Machine

(*Handbook of Astronautical Engineering*, 1961)

Table 26.4. Superiority of Man and Machine in Various Activities

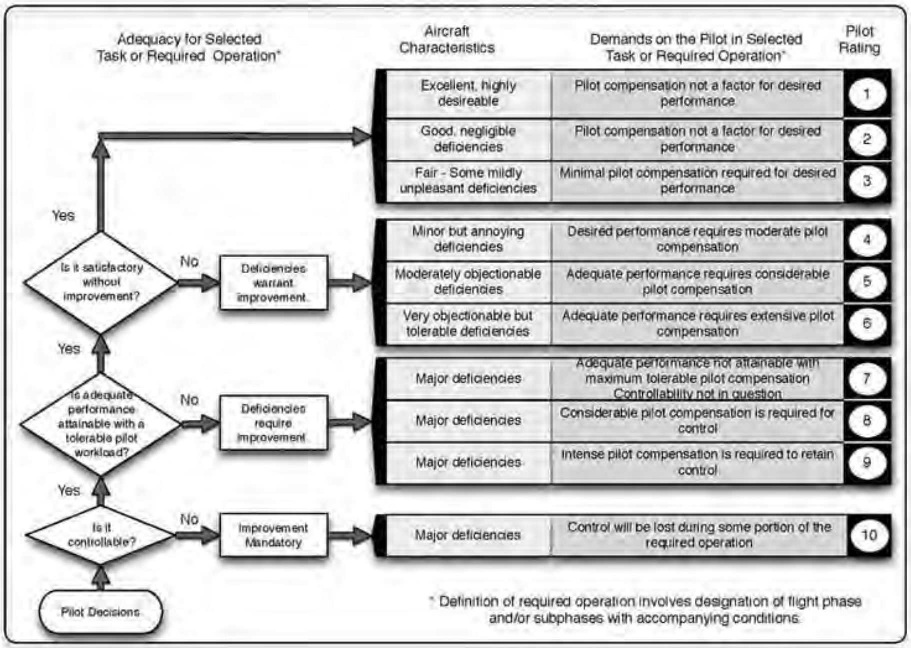
Man	*Machine*
Flexibility	Physical strength and power
Multipurpose adjustment	Speed of sensing
Multipurpose response	Speed of recognition
Redundancy	Speed of certain performances
Multipurpose sensitivity	Bandwidth
Communication	Speed of computation
Learning	Constancy of performance
Judgment	Repetitive performance
Inductive reasoning	Reliability
Understanding of essentials	Endurance
Establishment of hypotheses	Stability of memory
Taking risks	Short-term storage capacity
Problem solving	Complete erase capability
Pattern interpretation	Conformity
Decision making	Reaction time
Ingenuity and intuition	Sensitivity to certain environmental conditions
Invention of new things	Insensitivity to certain environmental conditions
Utilization of subjective experiences	Simultaneous activity
Utilization of external means	
Design and construction of machines and equipment	
Integration of internal and external stimuli	
Concluding	

Performance Issues for Manned Spaceflight

- Flexibility, learning, and judgment
- Information bandwidth, display, and communication
- Pre-flight training
- Performance variation
- Extra-vehicular activity
- Physical labor
- Physical labor
- Endurance
- Ergonomics
- Control systems
- Re-entry systems and recovery
- Tools and equipment
- Recycling

Cooper-Harper Pilot Opinion Rating

(NASA TN D-5153, 1969)



Cooper-Harper Pilot Opinion Rating

(NASA TN D-5153, 1969)

DEFINITIONS FROM TN-D-5153

COMPENSATION

The measure of additional pilot effort and attention required to maintain a given level of performance in the face of deficient vehicle characteristics.

HANDLING QUALITIES

Those qualities or charcteristics of an aircraft that govern the ease and precision with which a pilot is able to perform the tasks required in support of an aircraft role.

MISSION

The composite of pilot-vehicle functions that must be performed to fulfil operational requirements. May be specified for a role, complete flight, flight phase, or flight subphase.

PERFORMANCE

The precision of control with respect to aircraft movement that a pilot is able to achieve in performing a task. (Pilot vehicle performance is a measure of handling performance. Pilot performance is a measure of the manner or efficiency with which a pilot moves the principal controls in performing a task.)

ROLE

The function or purpose that defines the primary use of an aircraft.

TASK

The actual work assigned a pilot to be performed in completion of or as representative of a designated flight segment.

WORKLOAD

The integrated physical and mental effort required to perform a specified piloting task.

Cooper-Harper Ref. NASA TND-5153

Human Space Experience to April 2016

- Continuous human space presence since Oct. 31, 2000
- Total people in space: 544
- Total person-days: 47,930
- Most space flights: Jerry Ross and Franklin Chang-Diaz (7)
- Cumulative spaceflight record: 878 days (Gennady Padalka)
- Single mission record: 438 days (Valeri Polyakov)
- Total ISS EVAs (2/16): 193
- Total ISS EVA time (2/16): 1205 hr
- EVA record: 16 (Anatoliy Solovyov)
- Longest EVA: 8hr 56 min (Susan Helms and James Voss)

Physical Issues for Manned Spaceflight

- Physiology
  - Loss of bone and muscle mass
    - Intensive exercise regimen
  - Fluid redistribution to upper body
  - Disruption of vision due to intracranial pressure
- Life support
  - Breathing and pressurization
    - Exposure to vacuum
  - Nutrition and hydration
  - Rest and work cycles
  - Thermal environment
    - Temperature extremes
  - Acoustic noise level
  - Waste disposal

https://en.wikipedia.org/wiki/Effect_of_spaceflight_on_the_human_body

Physical Issues for Manned Spaceflight

- Acceleration level during launch and re-entry
- Effects of weightlessness
- Angular rate and orientation
  - Motion sickness
- Radiation hazards
  - Cosmic radiation
  - Van Allen belts

Human Acceleration Tolerance

(NASA TN D-337, 1960)

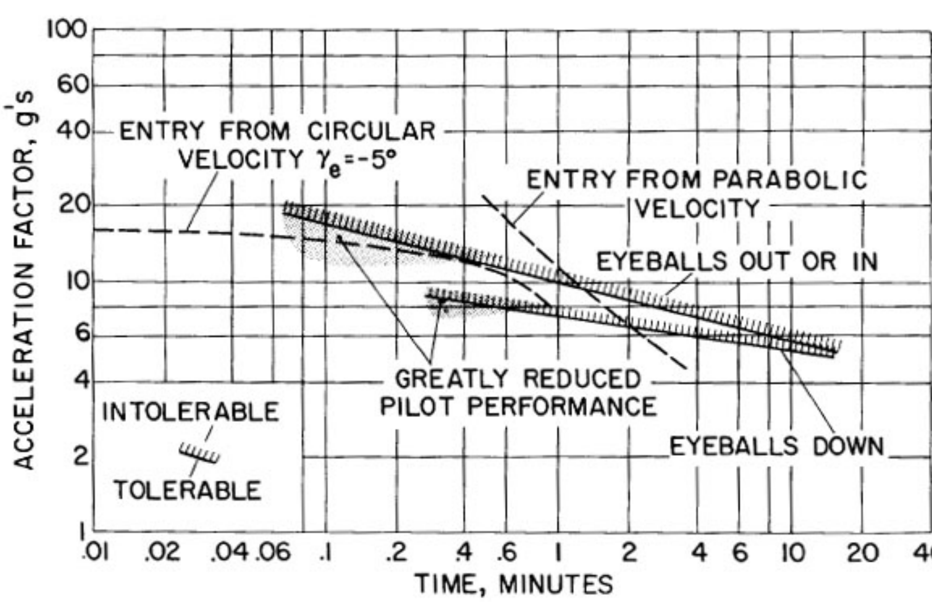


Figure 10.- Time tolerance to acceleration boundaries.

Effect of Drag/Mass on Direct Reentry Deceleration

(*Handbook of Astronautical Engineering*)

Flight path angle = constant
Lift = 0

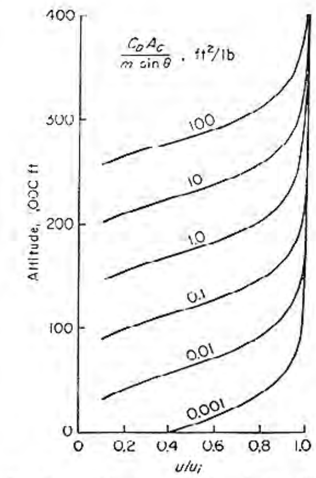


Fig. 10.13 Velocity variation during direct penetration of the earth's atmosphere.

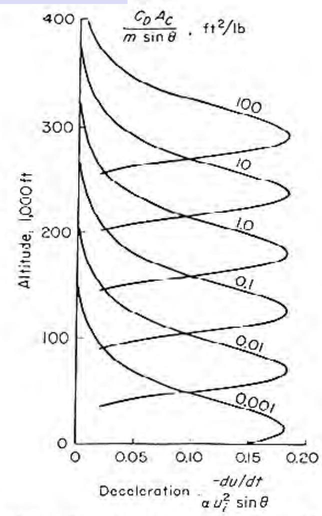
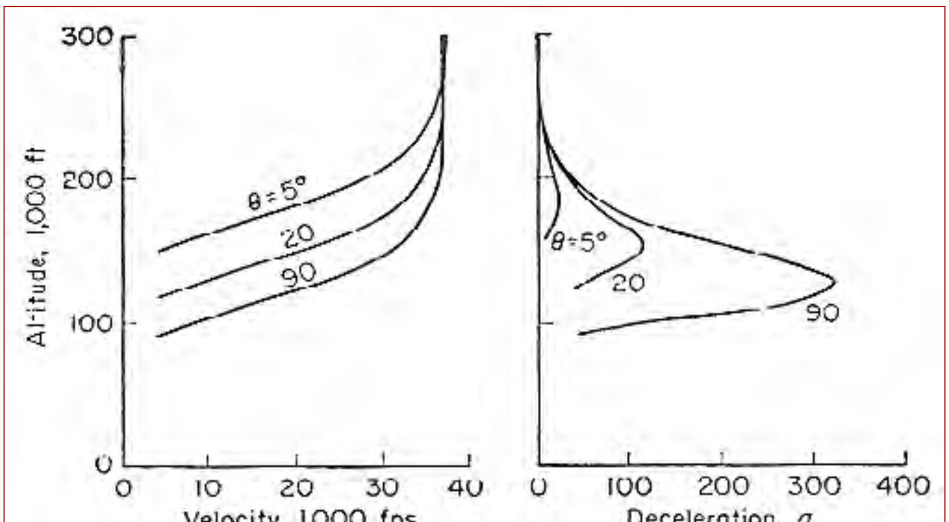


Fig. 10.14 Variation of deceleration with altitude for direct entry into the earth's atmosphere.

Effect of Flight Path Angle on Direct Reentry Deceleration

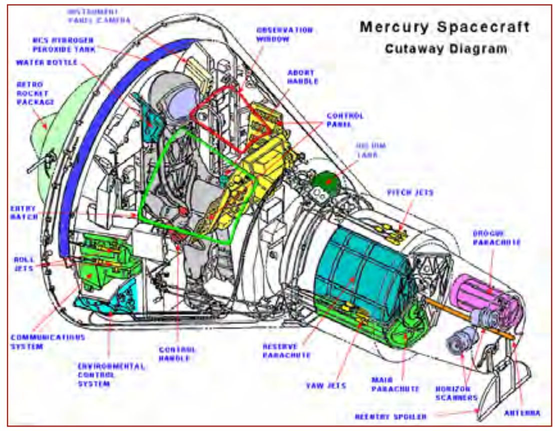
(*Handbook of Astronautical Engineering*)

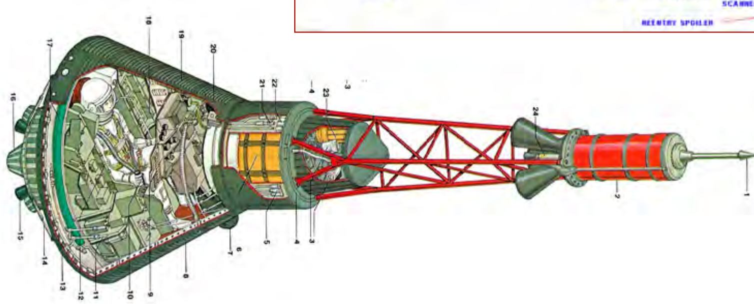
$C_D S/m$ = 0.1



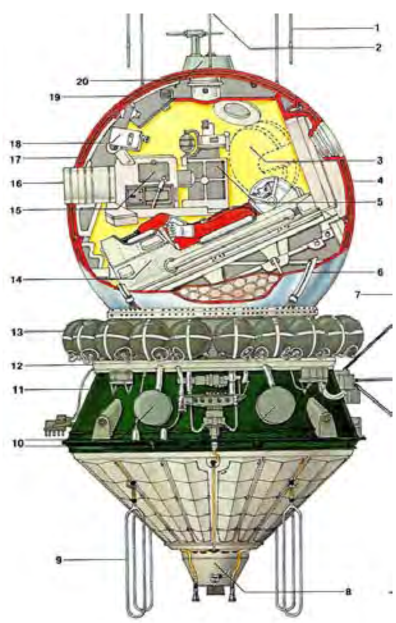
Mercury

- One crew member
- Command module
- 1,935 kg
- Conical reentry capsule
- Large-radius heat shield
- Negligible reentry crossrange capability
- Parachute recovery of capsule and astronaut
- 9-g reentry
- Low earth orbit





Vostok



- One crew member
- 2,460 kg
- Command + service modules
- Spherical reentry capsule
- Small-radius heat shield
- Negligible reentry crossrange capability
- Parachute recovery of capsule
- Cosmonaut lands on personal parachute
- 8-g reentry
- Low earth orbit

Effect of Lift/Drag on Reentry Deceleration

(*Handbook of Astronautical Engineering*)

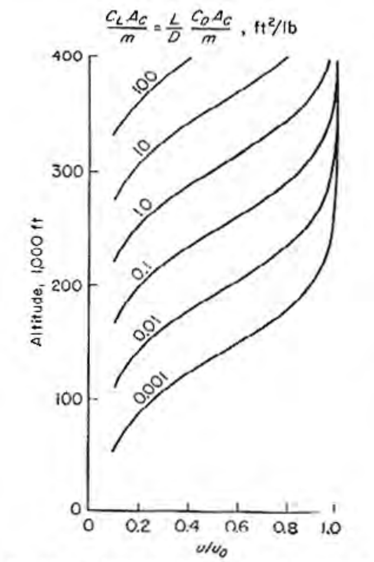


FIG. 10.17 Velocity variation with altitude for entry into the earth's atmosphere of a body with gasdynamic lift.

***L/D* = 1 to 3**

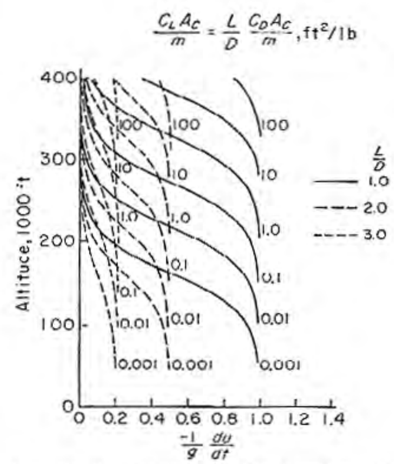
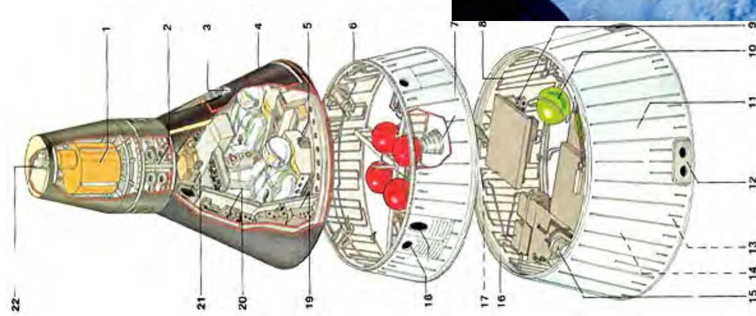


FIG. 10.18 Variation of deceleration with altitude for entry into the earth's atmosphere of a body with gasdynamic lift.

Gemini

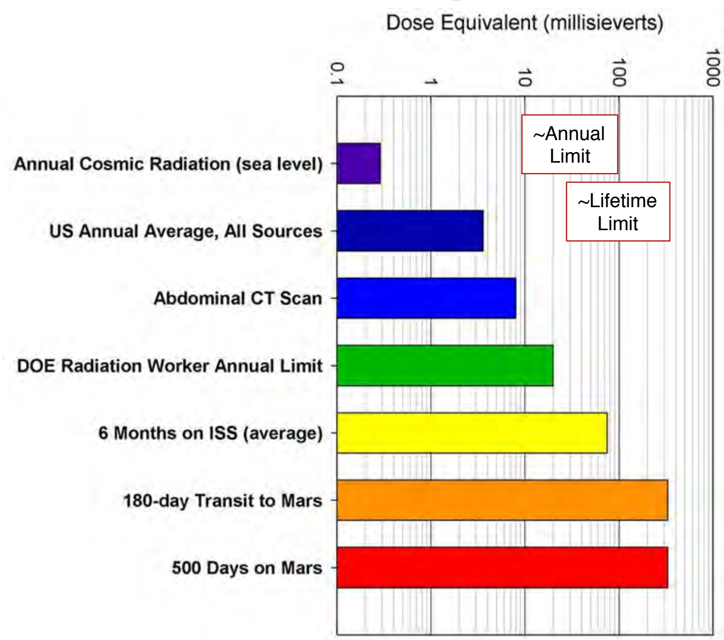
- 2-person crew
- 10 manned missions
- Up to 7 days in orbit
- Low reentry crossrange capability
- Extravehicular activity
- Rendezvous and docking
- Formation flying



"Pete" Conrad, '53, two Gemini missions, 1965 and 1966

Apollo's Return to Earth

Radiation Exposure



Indicated limits are controversial

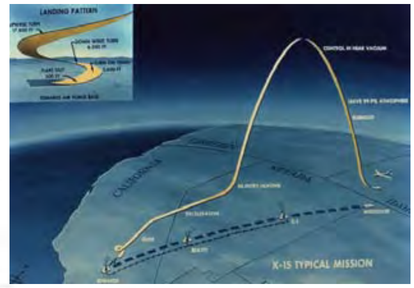
Psychological Issues for Manned Spaceflight

- Psychology
  - Egocentricity (“autonomization”)
  - Isolation and monotony
  - Increased holistic respect for Earth
- Psychiatry
  - Transient anxiety or depression
  - Fatigue, irritability, sleep disorder
  - Readjustment on return to Earth
- Sociology
  - Bonding of vehicle crew
  - Importance of supportive mission commander
  - Lack of confidence in ground personnel
  - Misunderstandings among crew from different cultures

Space Medicine

- Cardiac rhythm disturbance
- Decompression sickness
  - Transition from air to oxygen for EVA (“nitrogen purge”)
  - Barotrauma
- Decreased immune response
- Medications
- Health and medical emergency
  - Procedures and protection
  - Use of ultrasound diagnostics in space
  - Intervention, e.g., robot-assisted surgery

X-15: The First US Spaceplane



1st powered flight: 1959
Maximum altitude: 108 km, 1963
Maximum speed: 7,273 km/hr, 1967
USN Commander Forrest Petersen, Princeton AE, 4th X-15 pilot, 1960

Project Mercury Flights (manned)

Redstone
- 5/61, Shepard
- 7/61, Grissom

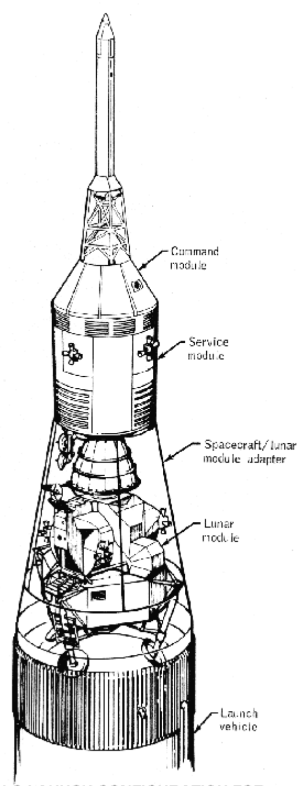
Atlas
- 2/62, Glenn
- 5/62, Carpenter
- 10/62, Schirra
- 5/63, Cooper

Project Gemini Flights

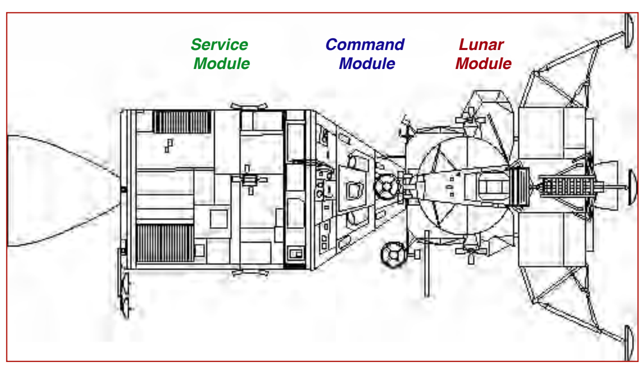
2/64 1/65 3/65 6/65 8/65 12/65 12/65 3/66 6/66 7/66 9/66 11/66

Unmanned | Manned

Apollo



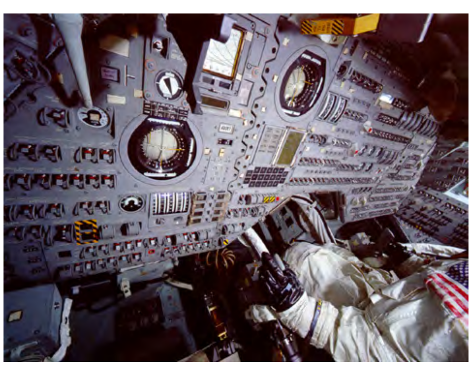
APOLLO LAUNCH CONFIGURATION FOR LUNAR LANDING MISSION



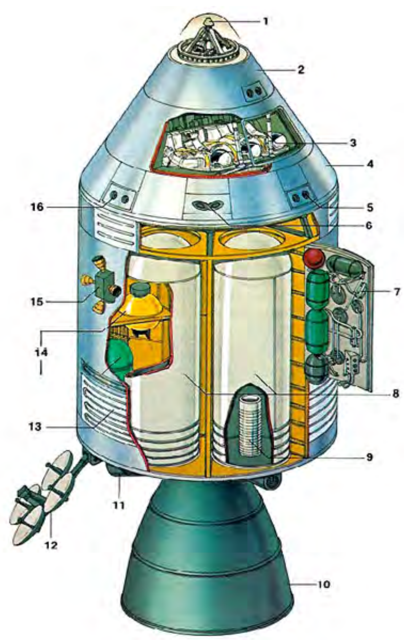
Similarities Between Verne's *Columbiad* and *Apollo*

- Launch from Florida at Cape Canaveral's latitude
- Size of capsule
- Number of astronauts
- Required launch velocity
- Time of flight
- Weightlessness
- Capsule recovery at sea

Apollo Command and Service Modules



- 3-person crew
- Upper and lower decks
- Autonomous guidance and control capability



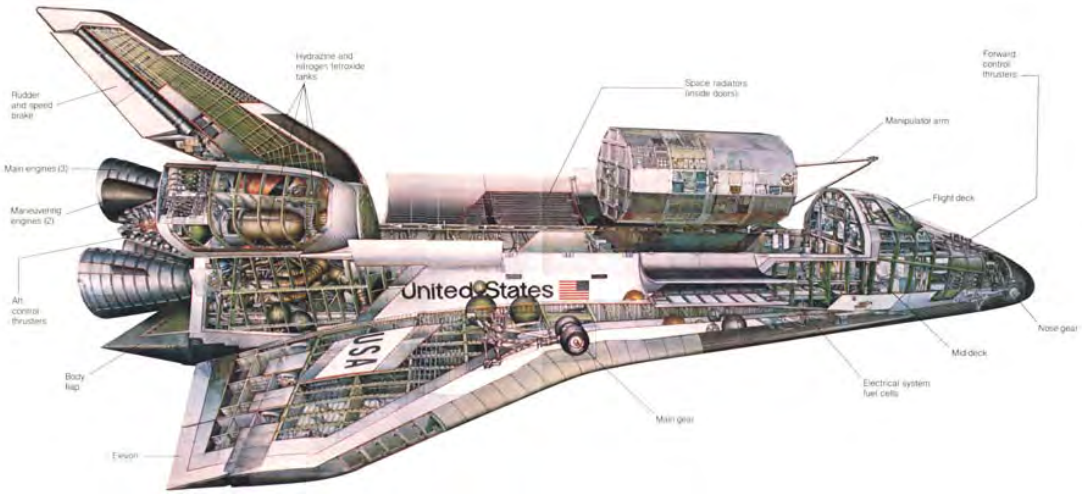
Saturn IB, 1966-1975

- 9 launches
  - Uprated S-I and S-IV stages
- AS-201, -202: sub-orbital
- AS-203: orbital
- AS-204: Apollo 1: Block 1, Jan 1967, no launch, loss of crew (Grissom, White, Chaffee)
- No Apollo 2 or 3
- Apollo 5: Jan 1968, LM test (unmanned)
- Apollo 7: Block 2, Oct 1968, 1st manned flight, (Schirra, Eisele, Cunningham)
- 3 flights to SkyLab, 1973
- Docking with Soyuz, 1975

Saturn V, 1968-1975

- New 1st and 2nd stages
- S-IVB became 3rd stage
- Apollo 4, 6: Unmanned
- Apollo 8: 1st to the Moon
- Apollo 9: orbital
- Apollo 10: 2nd to the Moon
- Apollo 11: 1st lunar landing
- Apollo 12: 2nd lunar landing
- Apollo 13: aborted lunar mission
- Apollo 14-17: successful lunar missions
- Skylab launch (2 stages)

Space Shuttle

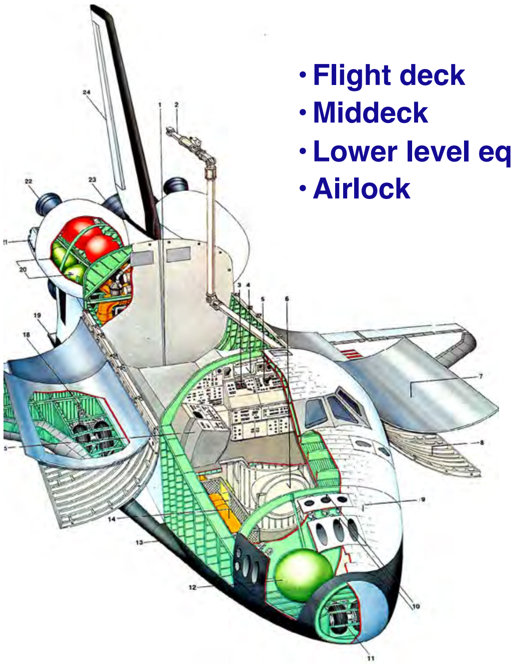


- 5 operational vehicles, 1 experimental vehicle
- 135 missions
- Retired in 2011
- *Challenger* and *Columbia* losses

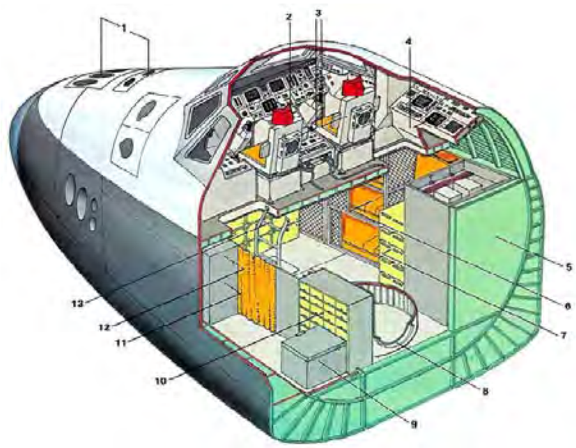
Pilot-Induced Oscillations

Uncommanded aircraft is stable but piloting actions couple with aircraft dynamics to produce instability

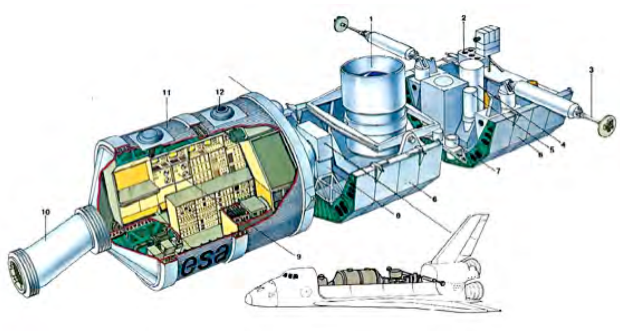
Space Shuttle Crew Compartment



- Flight deck
- Middeck
- Lower level equipment bay
- Airlock

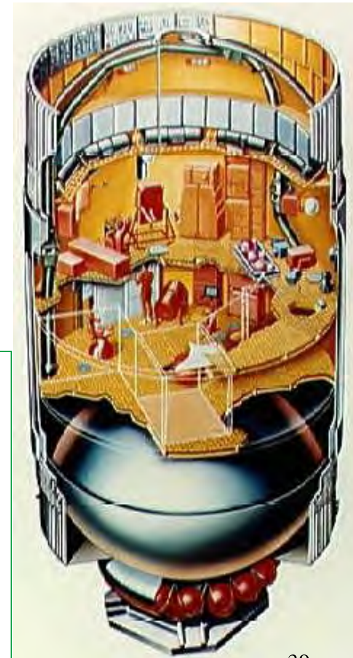


Space Shuttle: Spacelab Module



- Modular space station supplied by ESA
  - Spacelab module provides main laboratory
  - Spacelab pallet provides mounting base for experiments
  - Instrument pointing system
  - Tunnel to lower deck
  - Pressurized "igloo" for pallet-only missions
- Components flown on 25 Space Shuttle missions

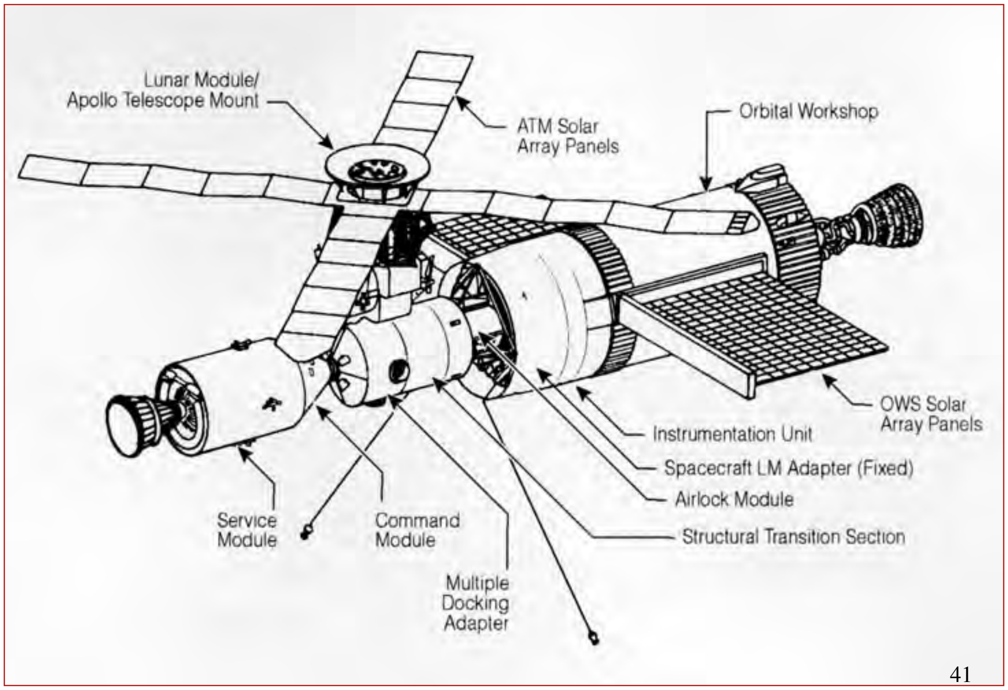
Space Stations: Skylab



- On orbit from 1973 to 1979
- 77,088 kg
- Station based on refined S-IVB stage
- Launched on modified Saturn V
- Damaged during launch
- Two of 3 crews commanded by Princeton alums
  - 1973: “Pete” Conrad, ‘53
  - 1973: Gerald Carr, *62

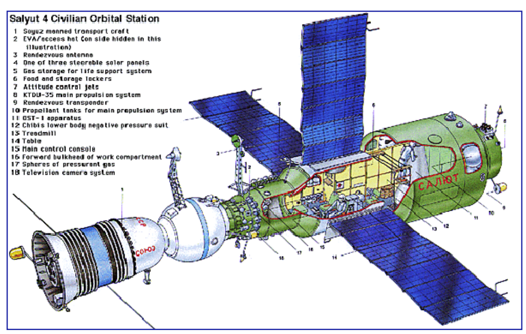
Charles “Pete” Conrad, ’51 (1930-1999)

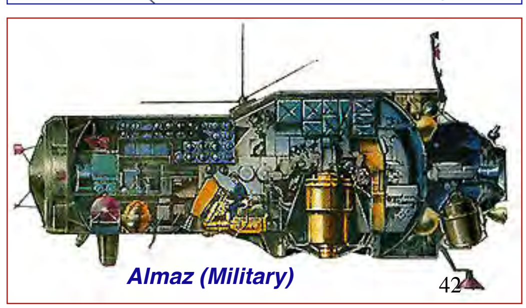
Space Stations: Skylab



Russian Space Stations

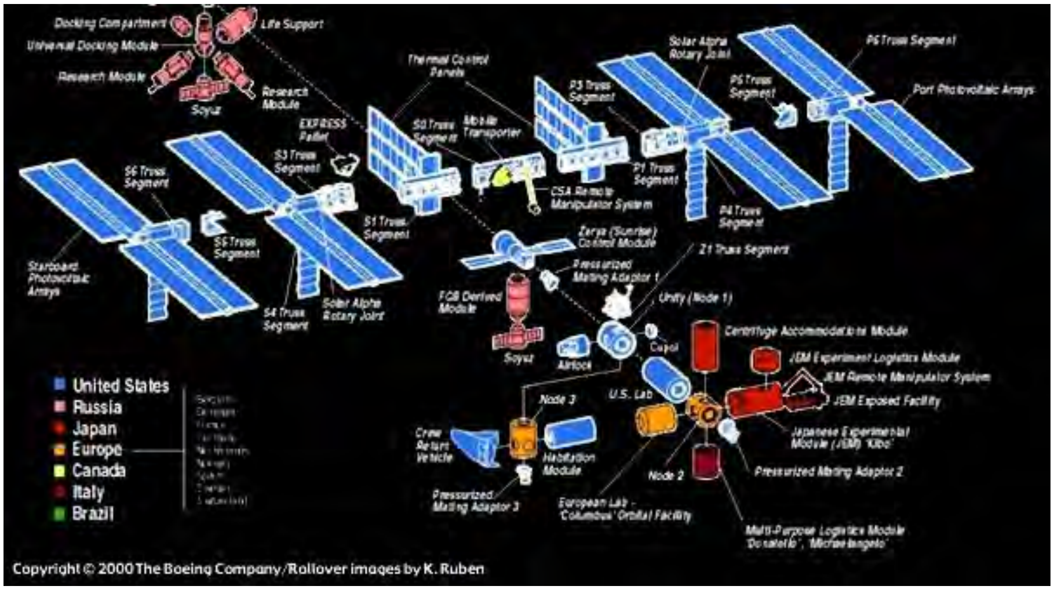
- 6 stations successfully orbited
- 31 crews launched to stations





International Space Station

http://iss.astroviewer.net/



International Space Station

- 4 laboratory modules orbited, 3 to follow
- ESA viewing cupola scheduled for 2009
- Docking cargo module scheduled for 2010

Today’s ISS Sighting Time

Sighting Location

Location: Princeton, New Jersey, United States

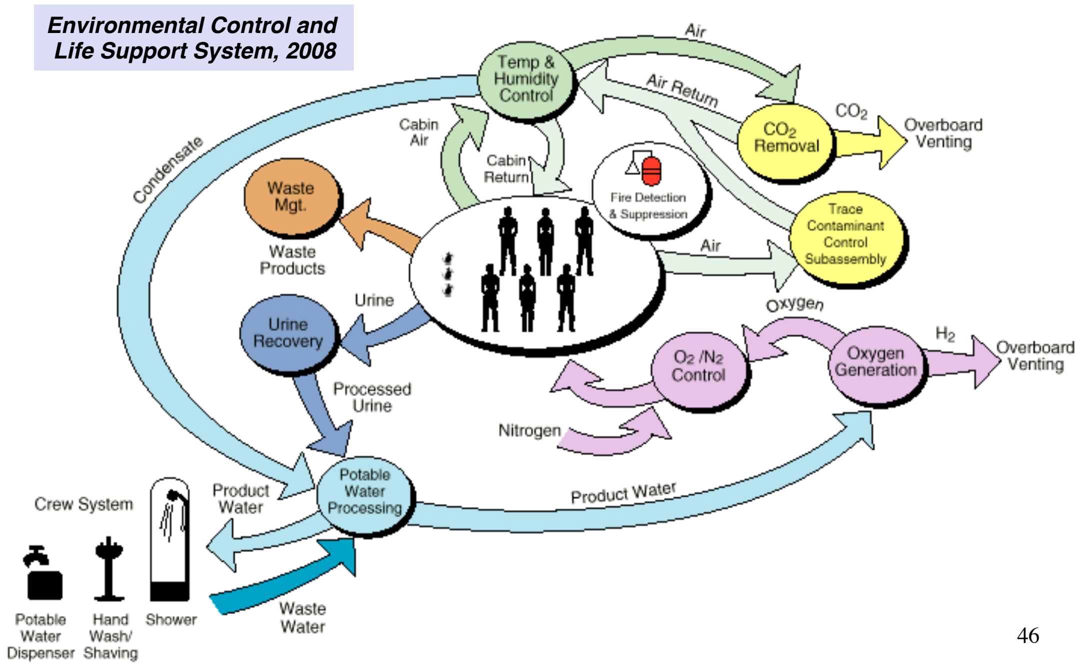
Sign Up for Alerts now! | RSS | Bookmark | Share | Print

The following ISS sightings are possible from Friday Apr 15, 2016 through Sunday May 1, 2016

Date	Visible	Max Height	Appears	Disappears	Share Event
Fri Apr 15, 9:29 PM	2 min	45°	21° above WNW	45° above SW	
Sat Apr 16, 8:37 PM	3 min	86°	35° above NW	20° above SE	
Sun Apr 17, 9:21 PM	2 min	18°	13° above W	17° above SSW	
Mon Apr 18, 8:29 PM	4 min	36°	27° above W	10° above SSE	
Wed Apr 20, 8:21 PM	3 min	15°	13° above WSW	10° above SSW	

45

Space Station Regenerative ECLSS Flow Diagram (Current Baseline)



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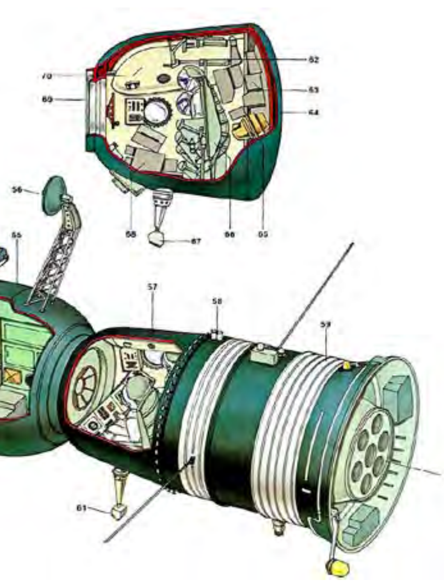
ExtraVehicular Activity

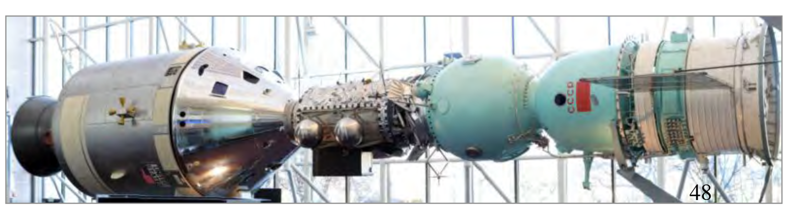
- Manned Maneuvering Unit included
  - Cold-gas attitude and translational control system (24 thrusters)
  - Astronaut hand controls
  - Used until 1986 *Challenger* accident
- Extravehicular Mobility Unit provides life support
- SAFER: simplified MMU for rescue

Soyuz Spacecraft and Launch Vehicle

- Orbital, reentry, and service modules
- Spinoff from Soviet manned lunar program

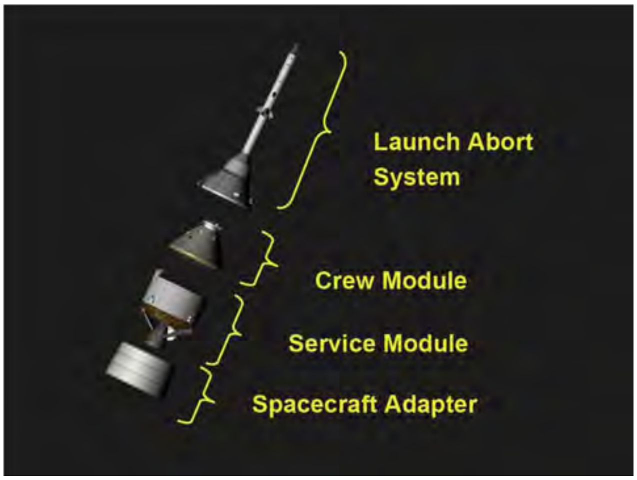


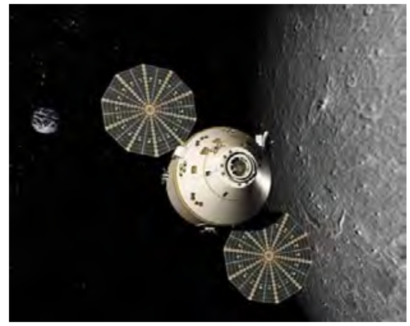
- 3-person crew
- Apollo-Soyuz at NASM

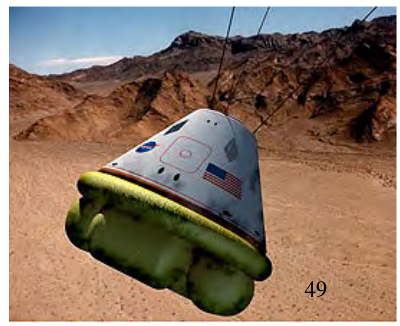


Orion Crew Vehicle

- Command Module (reusable)
- Service Module (expendable)
- 4-6 crew members

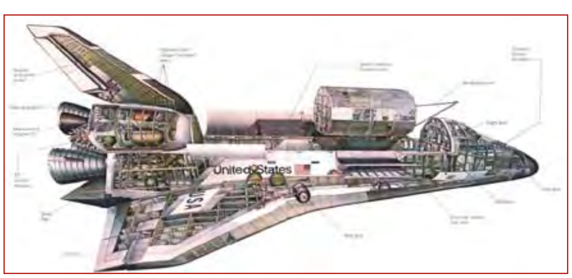


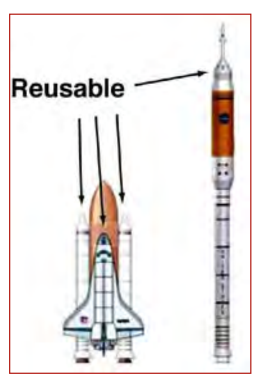




Orion/Ares vs. Space Shuttle

	Orion	Space Shuttle
Payload to LEO, kg	1,000 (est)	24,400
Payload from Orbit, kg	Neg.	12,700
Crew + Passengers	6	8 (11)
Reentry Cross-Range Capability, km	30	2,010
EVA Capability	No	Yes



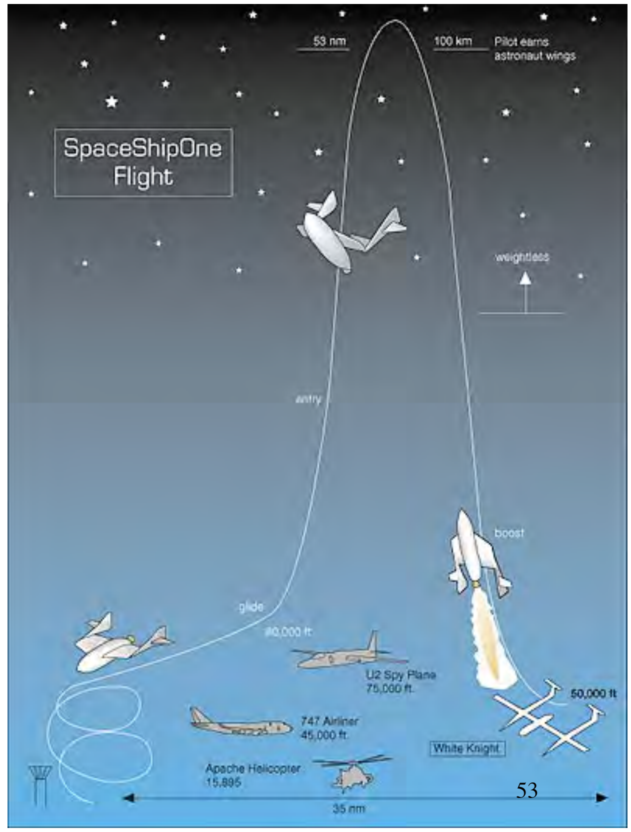


US and Foreign Manned Spacecraft

Space Tourism

SpaceShipOne

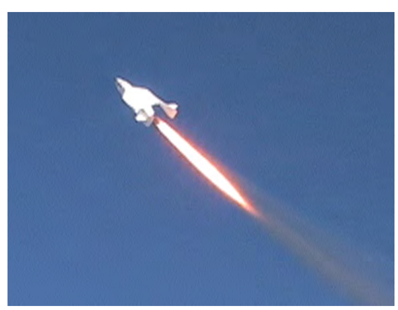
Flown above 100 km twice in 2 weeks in 2004 to win the Ansari X-Prize.



Princeton SpaceShipOne Test Pilot and Astronaut

- **Brian Binnie, MAE, MSE *78, exceeded M1.2 in 60-deg climb on December 17, 2003, 100th anniversary of the Wright Brothers first flight**

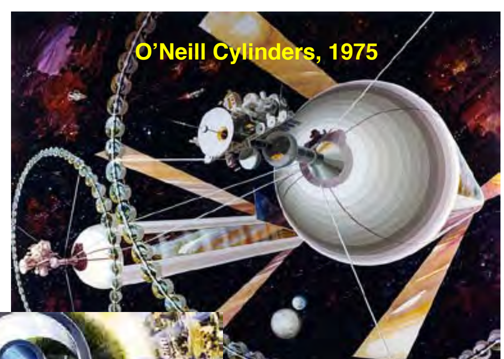
- **Brian won Ansari X-Prize and astronaut wings by flying to 367,442-ft altitude and broke X-15 record on October 4, 2004.**



Colonization of the Moon and Planets

https://en.wikipedia.org/wiki/Space_colonization

… or *L4* or *L5*



Next Time: System Engineering and Integration