

Benefits of a Single-Person Spacecraft for Weigh less Operations



Brand Griffin

August 15, 2012

Why Look at a Single-Person Spacecraft?

B Griffin

Past EVA Contributions

Samples



Retrieval/
Repair

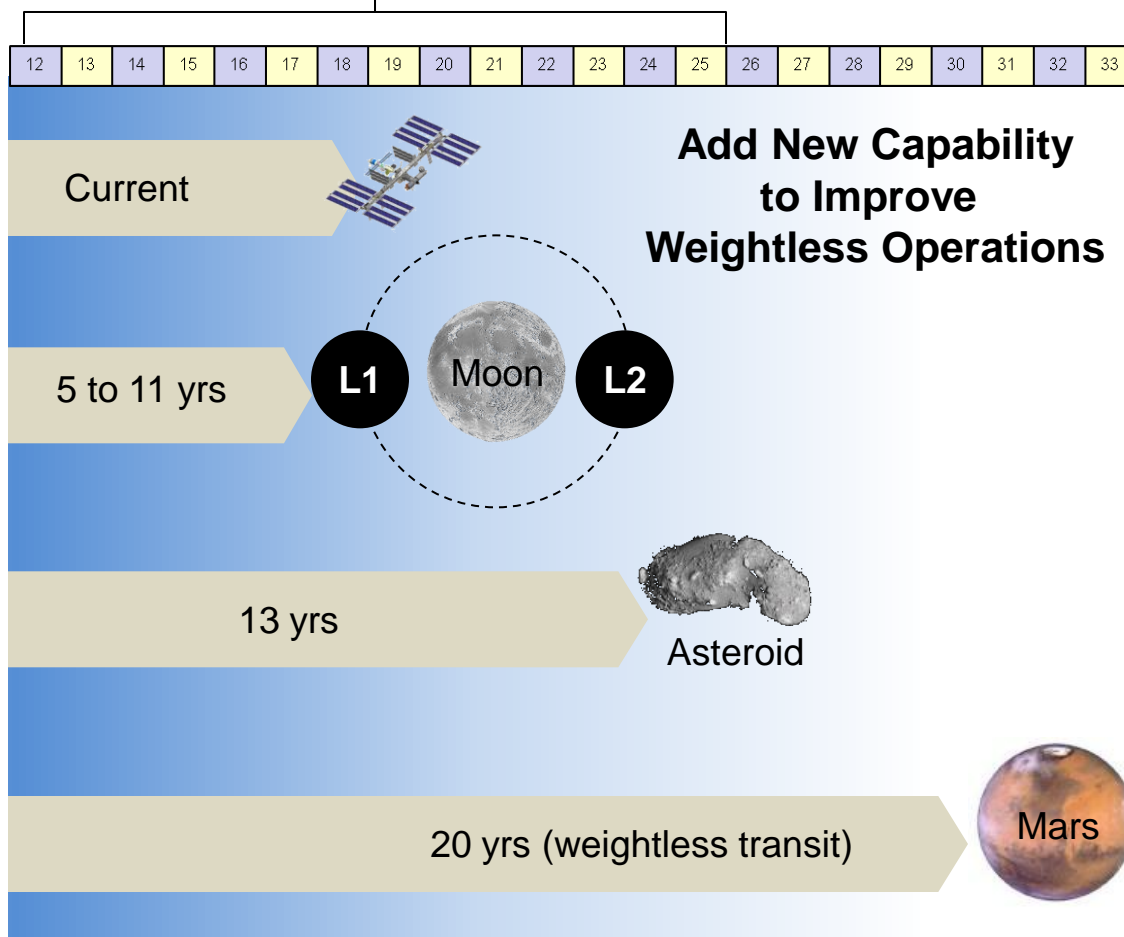


Assembly



Future NASA Plans Emphasize Weightless Operation

Weightless Operations 13+ years



Idea is Not New

B Griffin

Bottle Suit

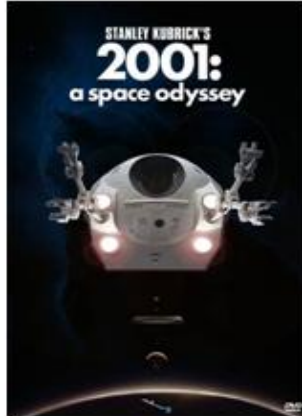
Von Braun



1954

Pod

2001 Sapce Odyssey



1968

MAWS

Griffin-Hudson



1985

SCOUT

Univ. of Maryland



2003

FlexCraft

NASA



2010

Unknown



MAWS II

Robotnaut arms
Howe-Griffin



2010

MAWS II

Alternative manipulators
Howe-Griffin



2010

FlexCraft Cherry Picker

NASA

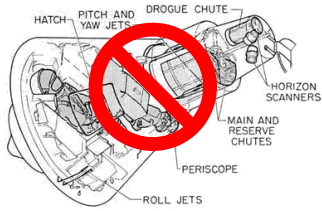


2011

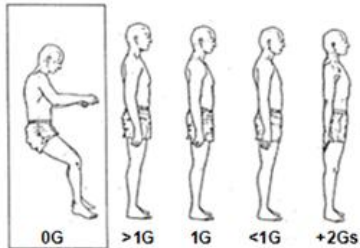
Single-Person Spacecraft

B Griffin

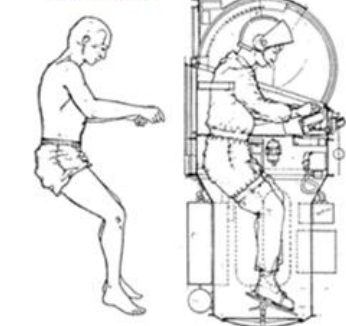
No Reentry



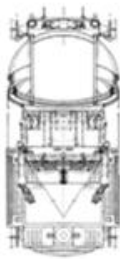
Weightless Operations



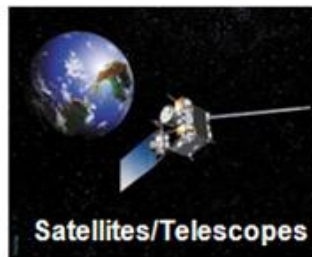
Zero-g Anthropometry for FlexCraft



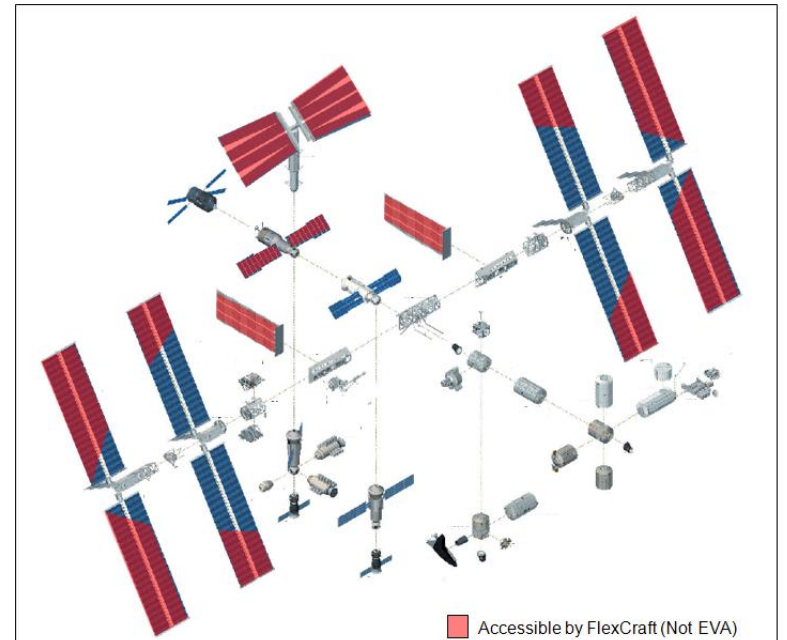
Human or Robotic



Venues



ISS Operations



Implications of Low Pressure

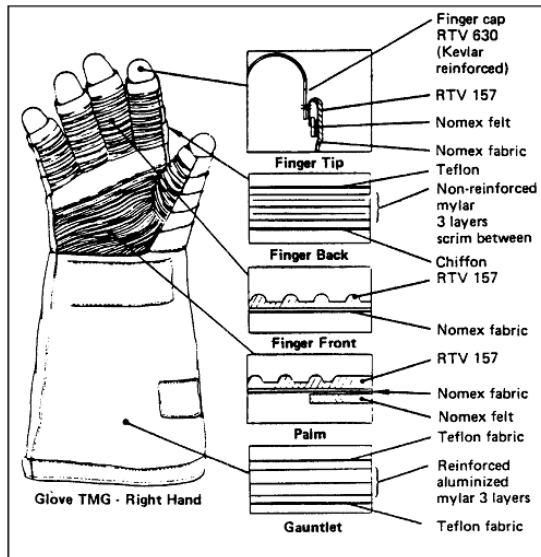
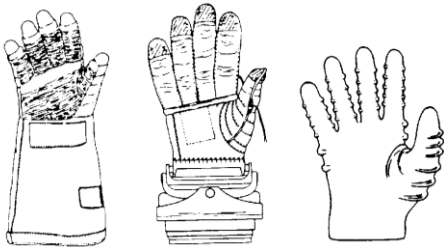
User

- Range of motion
- Tactile feedback
- Low forces
- Minimum fatigue
- Comfort

Design

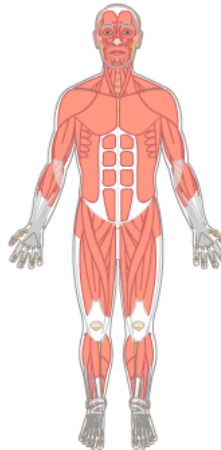
- Gas retention
- Restraint
- Thermal
- Micrometeoroid
- Puncture

CONFLICT



ISS Atmosphere

101.3 kPa (14.7 psi)



Prebreathe

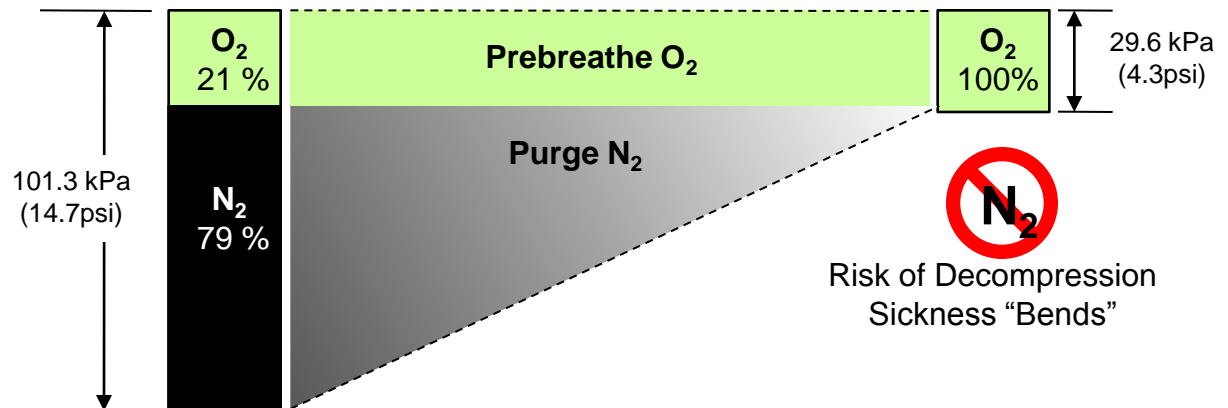


Low pressure space suit

29.6 kPa (4.3 psi)



Glove pressure determines suit pressure



Less Overhead Time

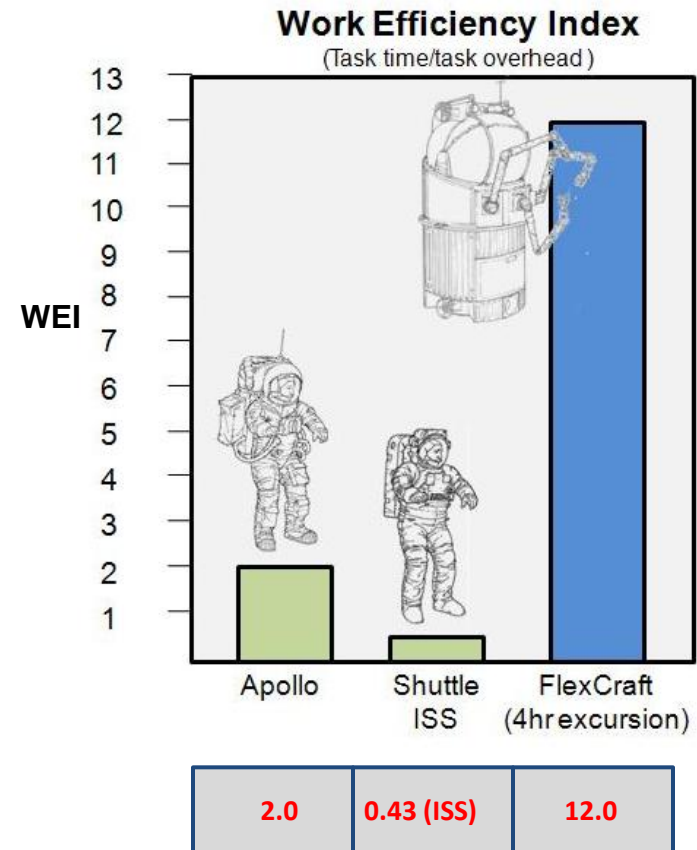
Better Work Efficiency Index (WEI)

B Griffin

EMU EVA Overhead Time

PREBREATHE PROTOCOL	Shuttle 10.2 Staged Decompression (12 hrs at 10.2)	ISS: 4 hour In Suit	ISS CEVIS Exercise (Using ISS O2)
EVA Overhead Activities	TIME IN MINUTES	TIME IN MINUTES	TIME IN MINUTES
Suit checkout	115	185	185
REBA powered hardware checkout	25	25	25
SAFER checkout	30	30	30
Airlock config	95	90	90
Consumables Prep	60	120	120
EVA prep - prebreathe related	Gone Away	0	80
EVA prep - EMU related	Gone Away	30	30
Suit donning & leak check	60	60	60
SAFER donning	Completed during Prebreathe	Completed during Prebreathe	Completed during Prebreathe
Purge	8	12	12
Prebreathe	75	240	60
Airlock depress	15	30	40
Airlock egress	15	15	15
Airlock ingress	15	15	15
Airlock repress	15	15	15
Suit doffing	25	25	25
SAFER doffing & stow	10	10	10
Post EVA processing	105	90	90
TOTAL	758	992	902
EVA WORK EFFICIENCY INDEX	0.51	0.39	0.43

↑
Egress
12.5-14 hr
↓
Ingress +
2.5 hr
↓



Direct access without prebreathing minimizes overhead

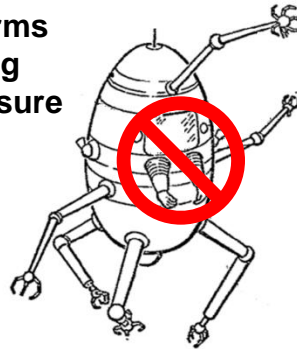
Many Parts and Adjustments are Required for Proper Suit Fit

Sizing Required to fit Population Extremes

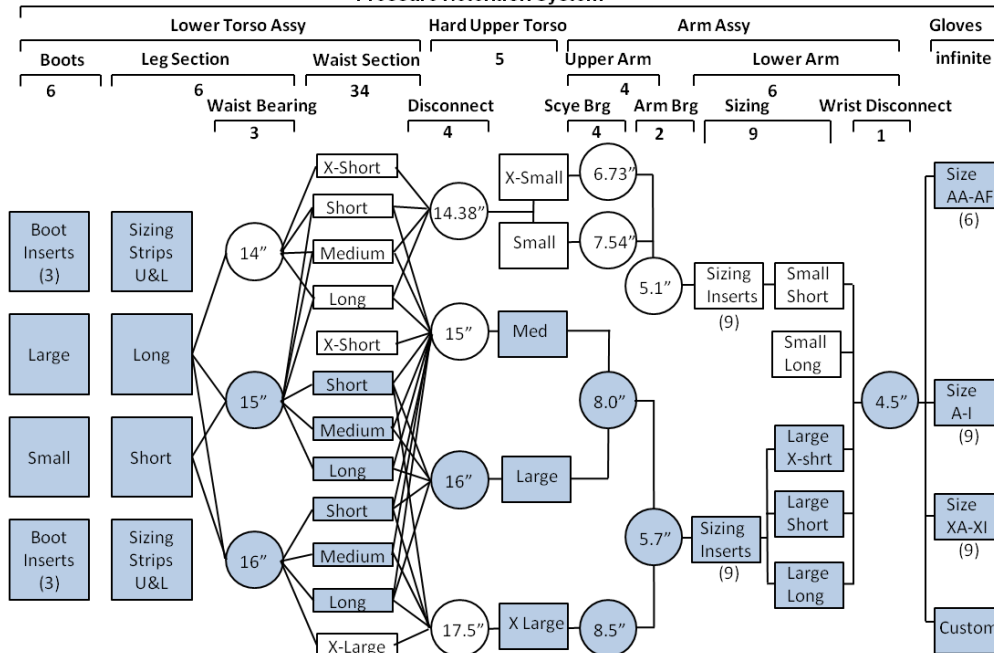


Avoid suit arms

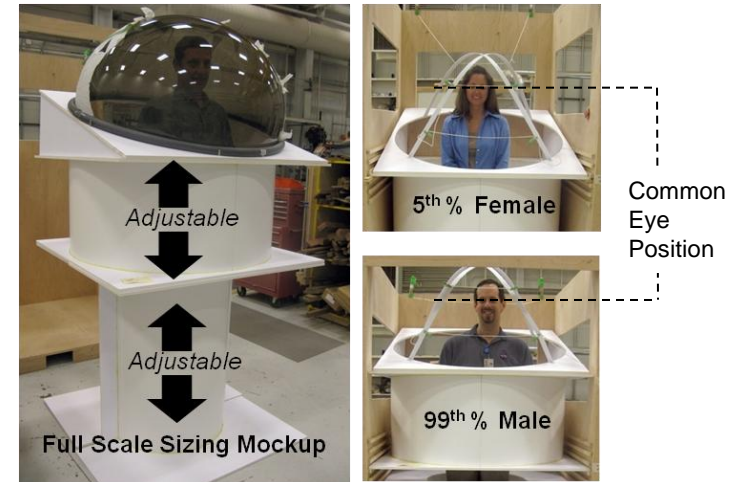
- Sizing
- Pressure



SPACE SUIT SIZING SYSTEM Pressure Retention System



One Size Fits All



*Pg 376, US Spacesuits, K. S. Thomas and H. J. McMann

Displays and Controls

B Griffin

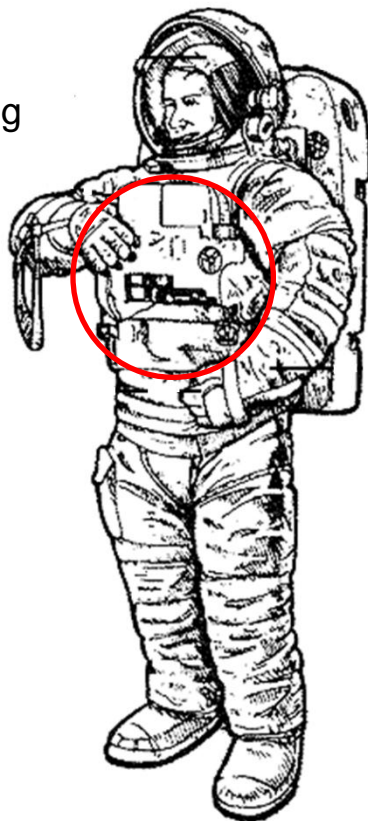
Space Suit

- Minimal displays (20 character LCD)
- Pressure glove dexterity
- Out-of-sight controls
- Sleeve mounted mirror
- Sleeve mounted checklist
- Take hand off job to operate
- Displays subject to local lighting

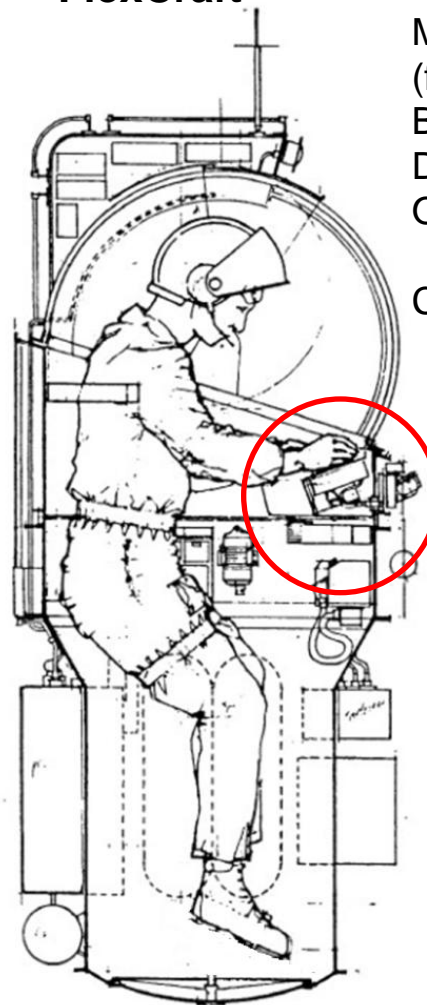
Alphanumeric Display



Cuff Check List



FlexCraft

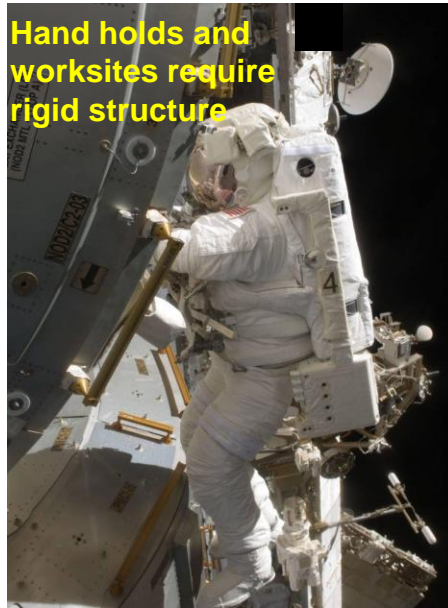
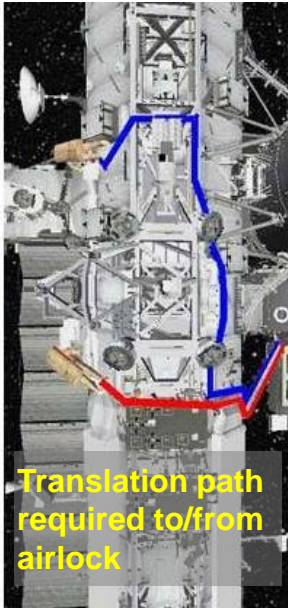


- Multiple displays (full color flat panels)
- Bare hand dexterity
- Direct visibility of displays
- Operate controls while manipulators on the job
- Cockpit-type environment

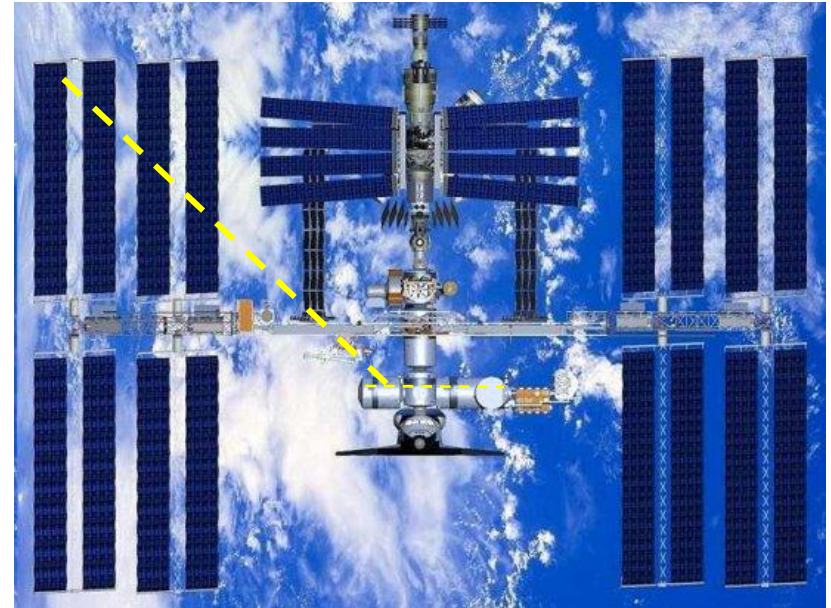
Getting to and from the Worksite

B Griffin

Hand-over-hand or SSRMS



Fly direct to worksite Emergency return is less than one minute



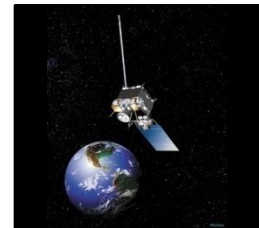
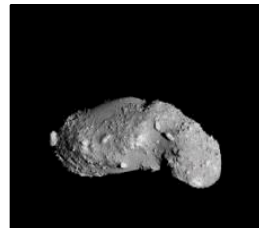
Asteroids, Satellite & Telescope



SAFER is for emergency recovery



To be determined:
Propulsion
Tools
ORUs
Experiments



Included:
Propulsion
Tools
ORUs
Experiments



Why Walk When You Can Fly

Translation Time

Space Suit

Translation time is...affected by the crewmembers¹

- Spacesuit configuration
- Tools carried
- Tethers which must be moved
- The “landscape” over which one is traveling

Increment 9 PRCM Replacement EVA

Activity	Time (min.)
Hatch to Strella	9
Translation to PMA1	15
Translation to SO	5
Tool config, trans to worksite	14
Stow tools, trans to SO	21
Translation to PMA1	10
Translation to Piers	16

Elapsed EVA
Translation
times

FlexCraft

“MMU can return to the airlock from the furthest point on Space Station (about 146.30 m (480 ft)) **in less than 1 minute.**”²

MMU ~ FlexCraft Performance

	MMU	FlexCraft
Delta V (m/s)	20*	19.5**
Nom. Range (m)	137	same
Operation (hr)	6	same
Propellant	GN2	same
Prop mass (kg)	5.9	14.2
No. Thrusters	24	same
Thrust (N)	7.56	same
Tank Press (kpa)	20,684	23,442

* 13.7 m/s useful delta v

** At 450 kg mass

¹ Extravehicular Activity Task Work Efficiency, C Looper and Z. Ney, SAE 2005-01-3014

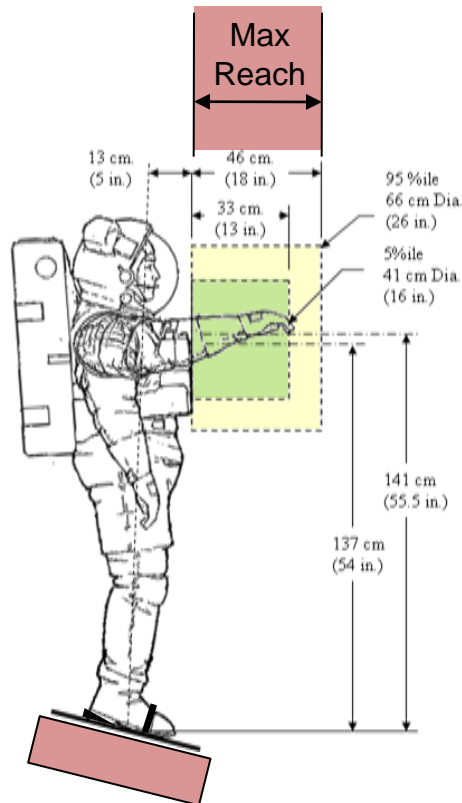
² Role of the Manned Maneuvering Unit for the Space Station, C. E. Whitsett, SAE

Quicker Translation is Safer and Means More Time on the Job

Foot Restraint Positioning Required for Two Free Hands

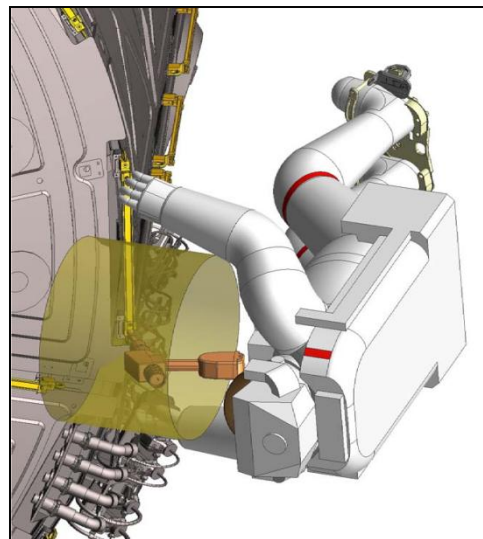
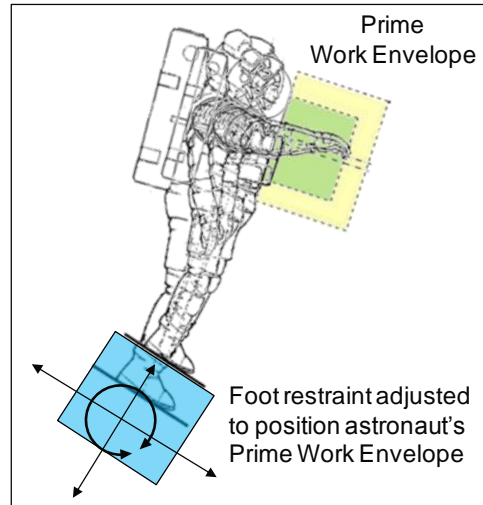
Prime Work Envelope

Vision and both hands in same location for all astronauts



Foot Restraint

Allows two hand operations
Reaction point for work loads



ISS

Not all areas EVA accessible
Prescribed translation paths
Requires worksite set up
SSRMS slow (for EVA support 15 cm/sec)
SSRMS not a cherry picker (requires IVA operations)

Asteroid (Near Earth Object)

Little to no gravity
No translation aids
No EVA propulsion (MMU retired)
Potential suit hazards

Satellite/Telescope

Only HST EVA serviceable
No translation aids
Potential suit hazards

Low Cost Simulator Training with in-Flight Refreshers

Space Suits

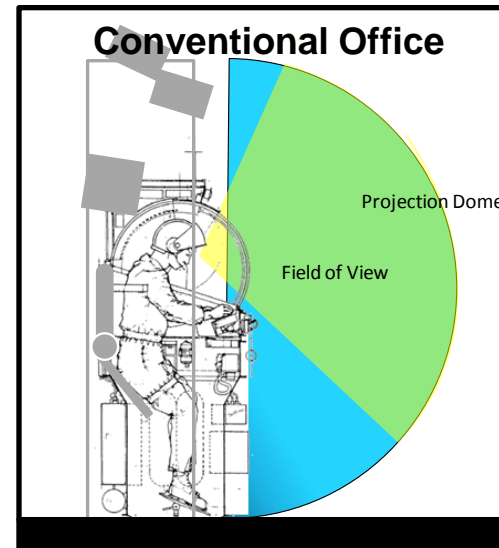


- Large unique facility
- Many skilled staff
 - Divers
 - Suit techs
 - Overhead crane
- Special equipment
- Many test personnel



- Safety issues
- Certification Training
- Pressurized gases
- Control room
- No on-orbit training

FlexCraft



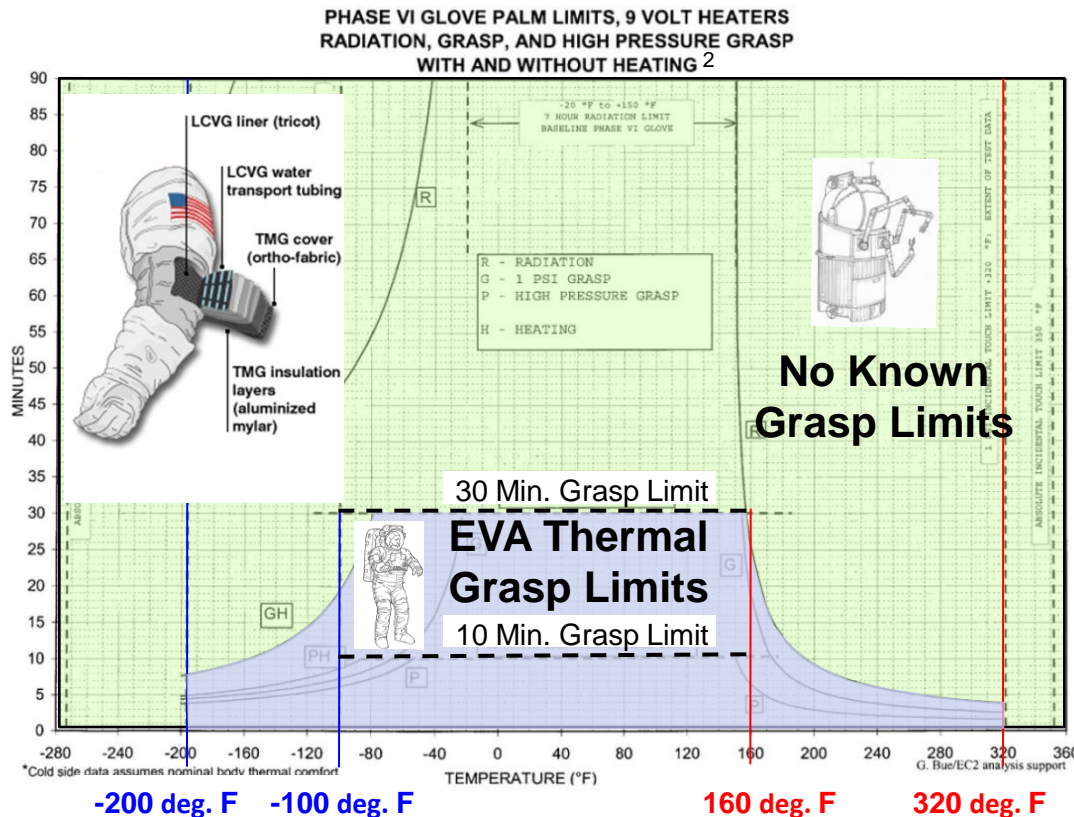
- Conventional Office
- Available projectors
- Available computers
- Simulation software
- Few test personnel
- No unique training
- No certification
- No safety issues
- On-orbit training
- Laptop platform



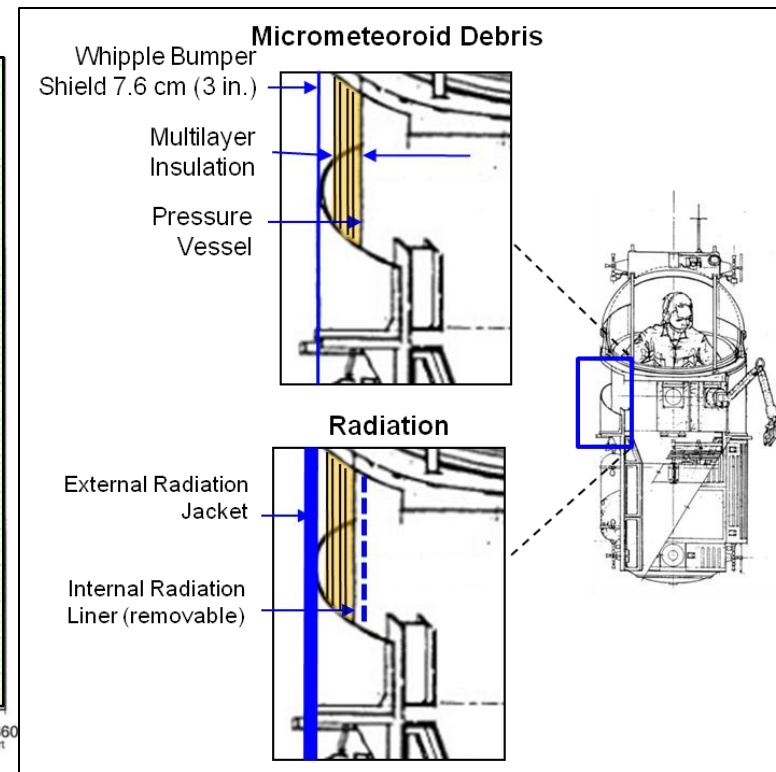
Grasp Limits and Protection

Thermal

Even with active heating, touch temperatures are limited to short durations and narrow ranges (-140 to +240°F or -96 to 116°C)¹



Micrometeoroid/Debris and Radiation



1. Advanced EVA Roadmaps and Requirements, Richard K. Fullerton, ICES01-2200
2. EMU Specification SVHS 7800, Rev BZ, pg 83
3. EMU Specification SVHS 7800, Rev BZ, 3.1.1.4.1

Suit-Induced Trauma

Space Suit

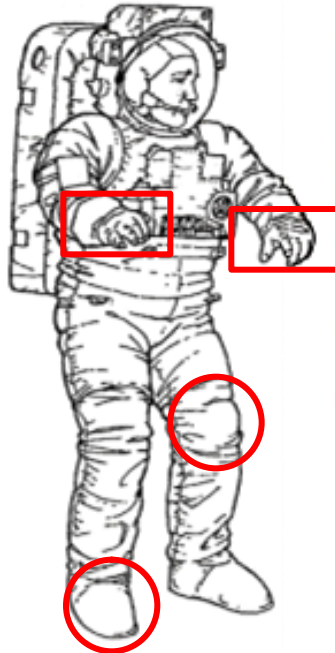
Suit induced trauma can occur even with minimal EVA time¹



Delaminated Fingernails²

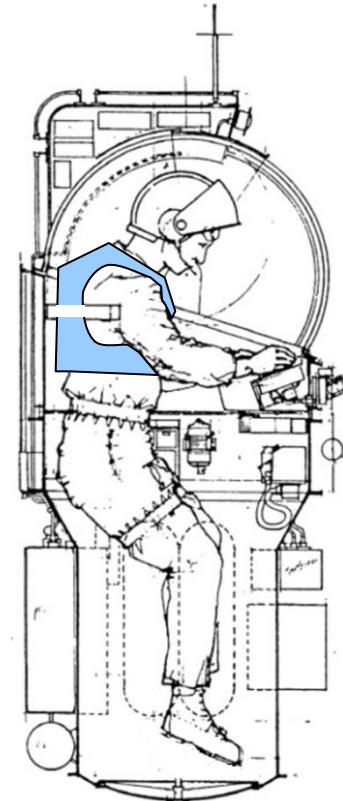


Swelling, Inflammation



Knee abrasion

FlexCraft No trauma anticipated



Restraint Vest
(No work loads)

¹ Extravehicular Activity – Challenges in Planetary Exploration, Carl Walz / Mike Gernhardt, 27 February, 2008, Third Space Exploration Conference and Exhibit, Denver, CO

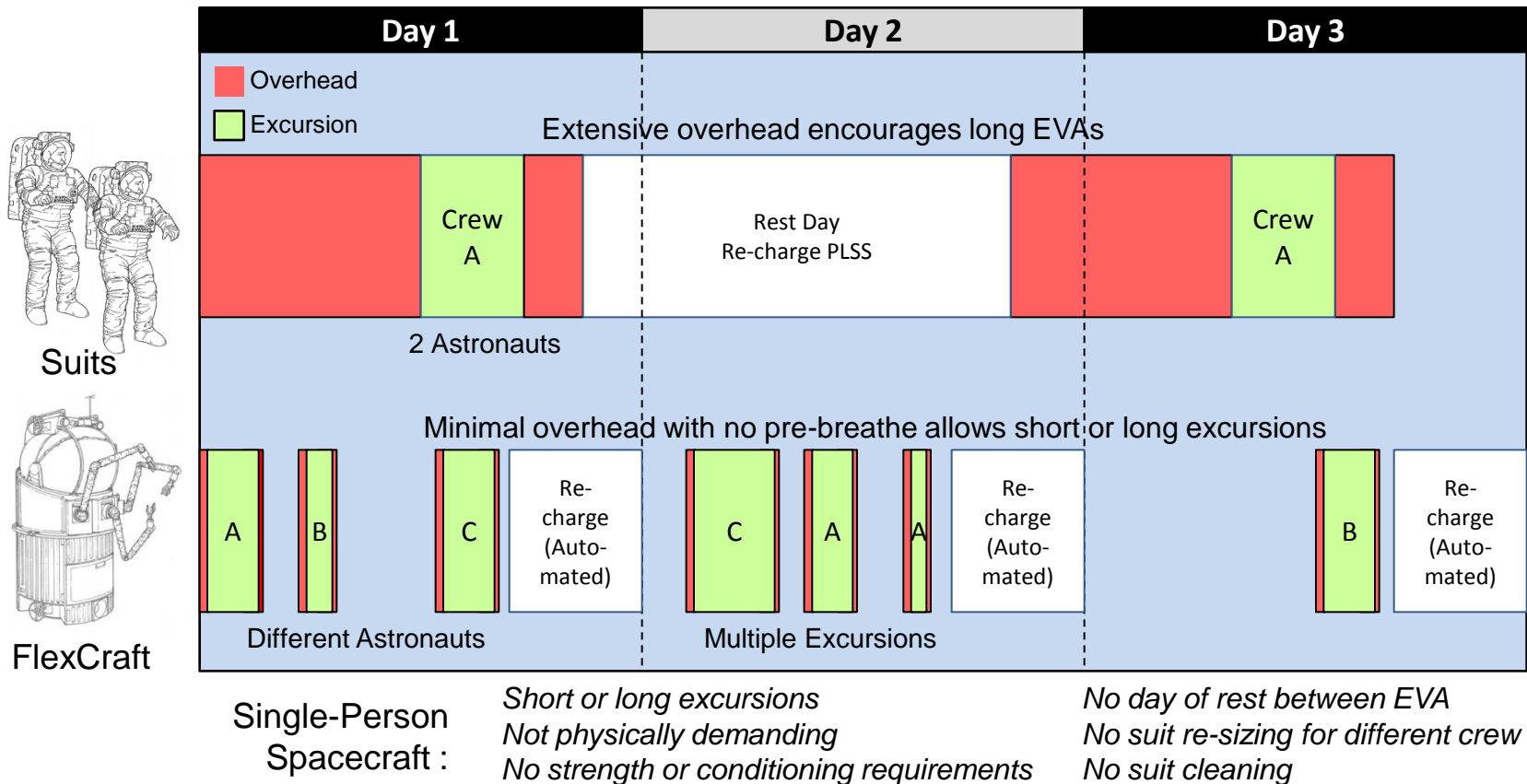
² Opperman RA, Waldie JM, Natapoff A, Newman DJ, Jones JA, Probability of spacesuit-induced fingernail trauma is associated with hand circumference, Aviation Space Environ Med 2010 Oct; 81(10):907-13.

Operations Flexibility

Mission length with alternating crew members

B Griffin

ISS Operations



No prebreathe with automated checkout allows rapid and frequent space access

Impact of Oxygen Environment

Space Suits and Host Spacecraft

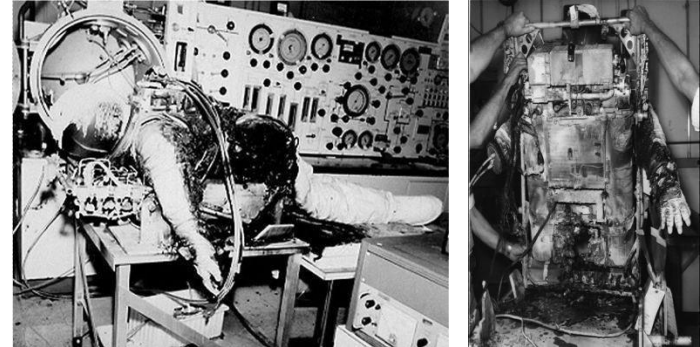
B Griffin

Fire and Materials in Different Oxygen Environments

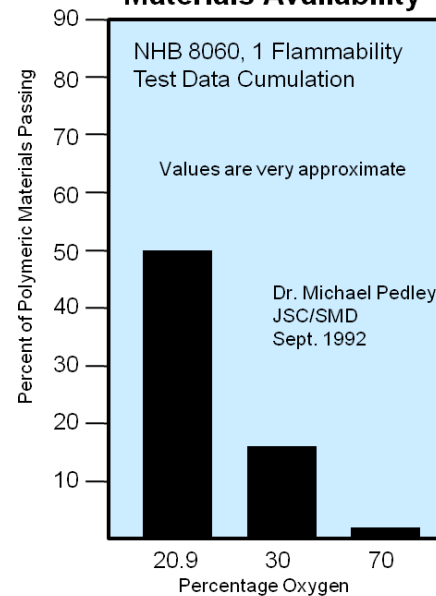
	14.7 psi/21% O ₂	5.2 psi/70-100% O ₂
Data Base	10000 reports	1000 reports
Fire Event History	High temperature spacecraft events controlled	Apollo 1 (204) & 13, hyperbaric chambers
Materials Control	Minimal	Significant, beta bagging, nonflammable paints/coatings, aluminum foil tape, containment, etc.
Materials Selection	Numerous options	Severely restricted
Off-the-shelf Hardware	Minimal modifications	Significant design changes, testing/analysis*
Fire Detection	Standard	Rapid events
Fire Suppression	Standard techniques effective	Ineffective
Propagation Potential/Self-Extinguishment	Most materials self-extinguish	Few materials self-extinguish, rapid propagation

Dr. Michael D. Pedley, NASA/JSC/ES5, Dennis E. Griffin, NASA/MSFC/EH02

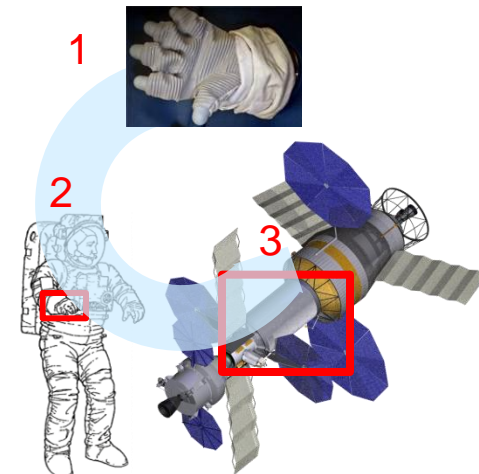
1980 Oxygen Suit Fire



Materials Availability



Low Pressure Spiral Glove Drives Host Requirements



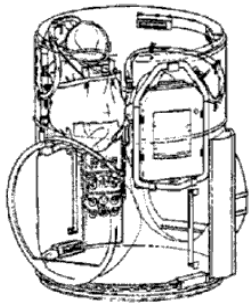
* **Examples:** (from Designing for EVA Applications, Gene Lutz, EVA Systems Project Office. Johnson Space Center, 13 February 2007)

- A \$150 Polar heart rate monitor may require \$200K (or more) of engineering testing, analysis and certification before it can be used in the Space Suit
- An emergency room EKG may require significant modifications to ensure the electrode leads do not detach from the crewmember in the Space Suit

Mass Comparison

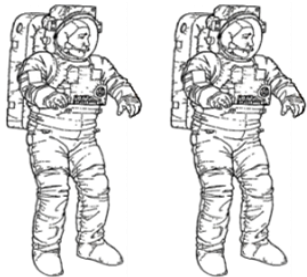
1012 kg (with airlock)

844 kg (without airlock (Orion), 4 EMUs)



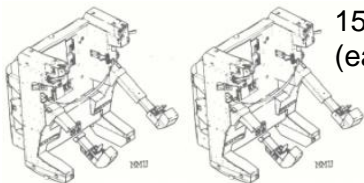
440 kg

Shuttle Airlock



136 kg
(each)

Extravehicular Mobility Unit (EMU)



150 kg
(each)

*Manned Maneuvering Unit (MMU)
(Representative, no longer available)*

452 kg
(Wet)



Category	Mass (kg)
Structures	121
Propulsion	51
Power	42
Avionics	40
Thermal	21
ECLSS	44
Docking Mechanism	20
GROWTH	41
DRY MASS	379
Non-Prop Fluids	1
Manipulators	58
INERT MASS	437
Total Less Propellant	437
Propellant	14
TOTAL GROSS MASS	452

460 kg
(Dry)



The 1965 Cessna 150E 1,010 lb (460 kg)

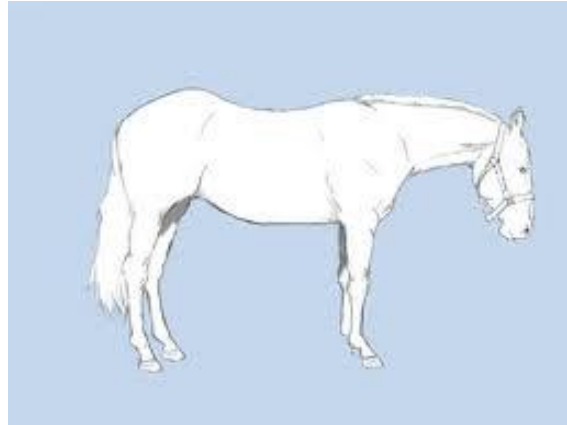
286 kg
(Dry with std equip)



New Skykit Savannah 630 lb (286 kg)

Step Function Capability

Faster Horses?



New Capability



"If I asked the people what they wanted, they would have said faster horses."



Henry Ford



Better "Weightless" Suits?



New Capability