

HexHab - 3D Printed Mars Habitat

Construction and Outfitting Sequence Timeline

Presentation to
TENTH JOINT MEETING of the SPACE RESOURCES ROUNDTABLE and the PLANETARY &
TERRESTRIAL MINING SCIENCES SYMPOSIUM
Colorado School of Mines
Golden, Colorado, USA
June 11-14, 2019

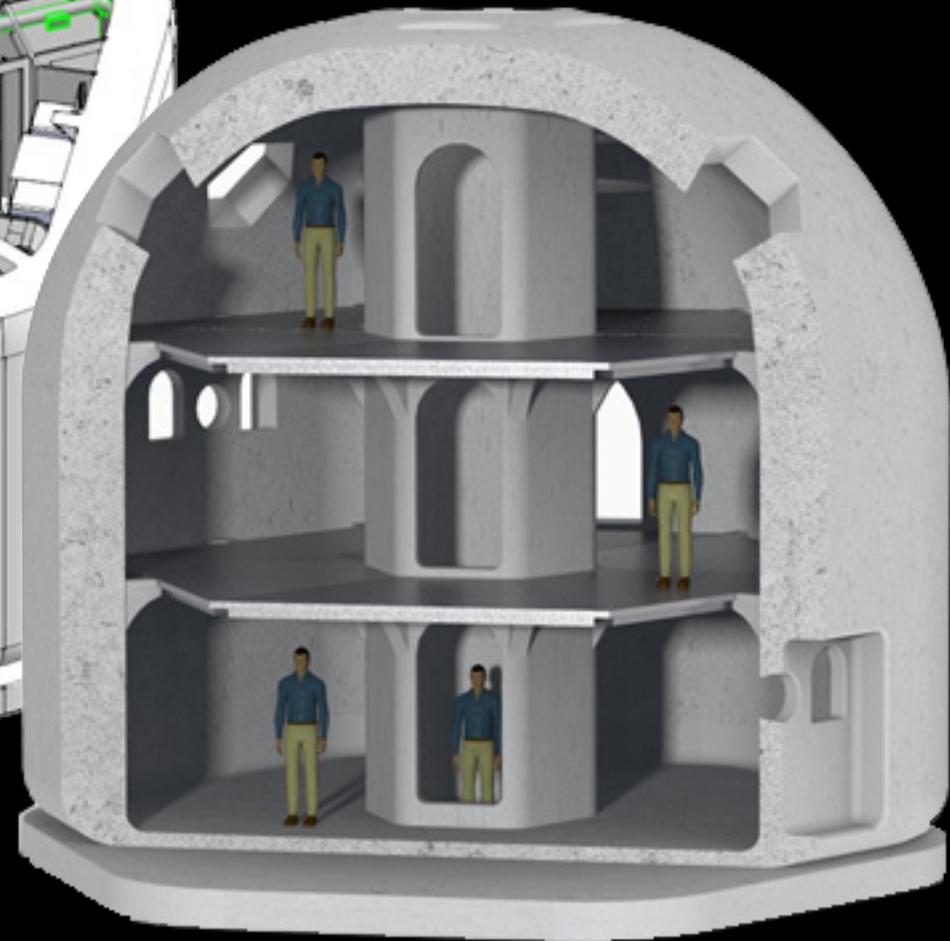
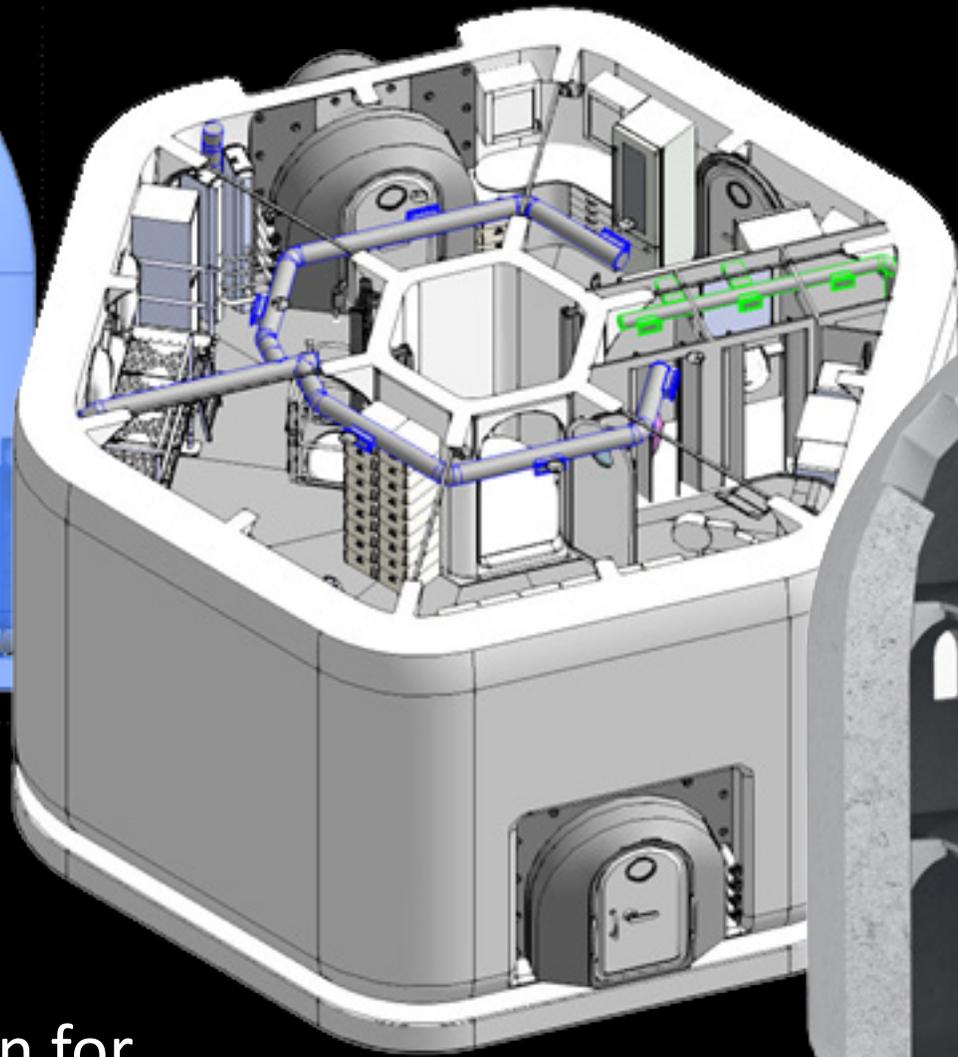
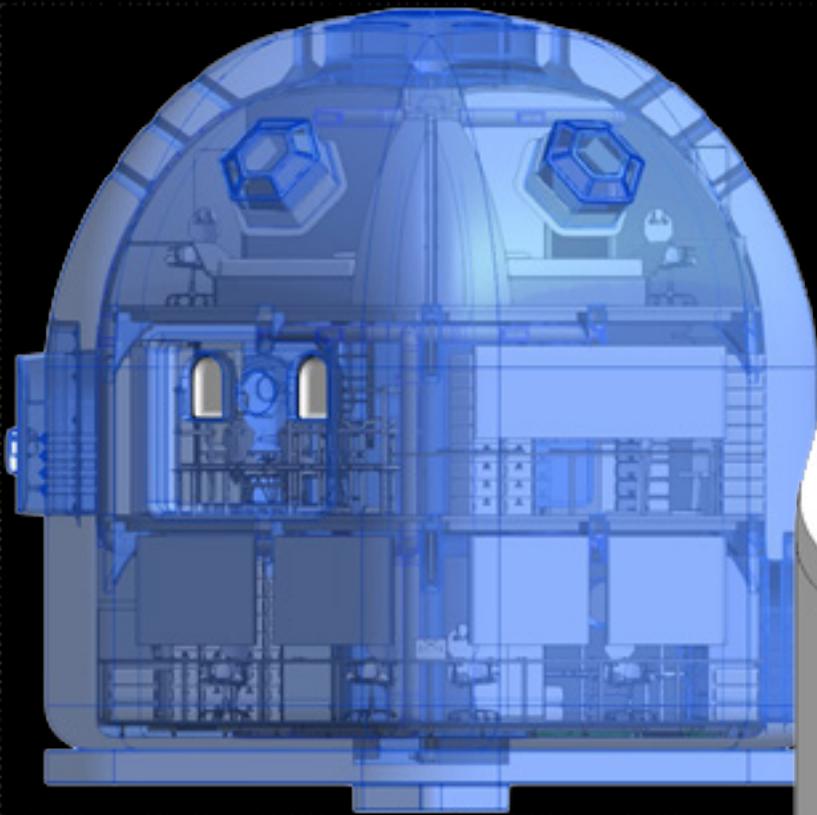
Samuel W. Ximenes, Space Architect

HexHab

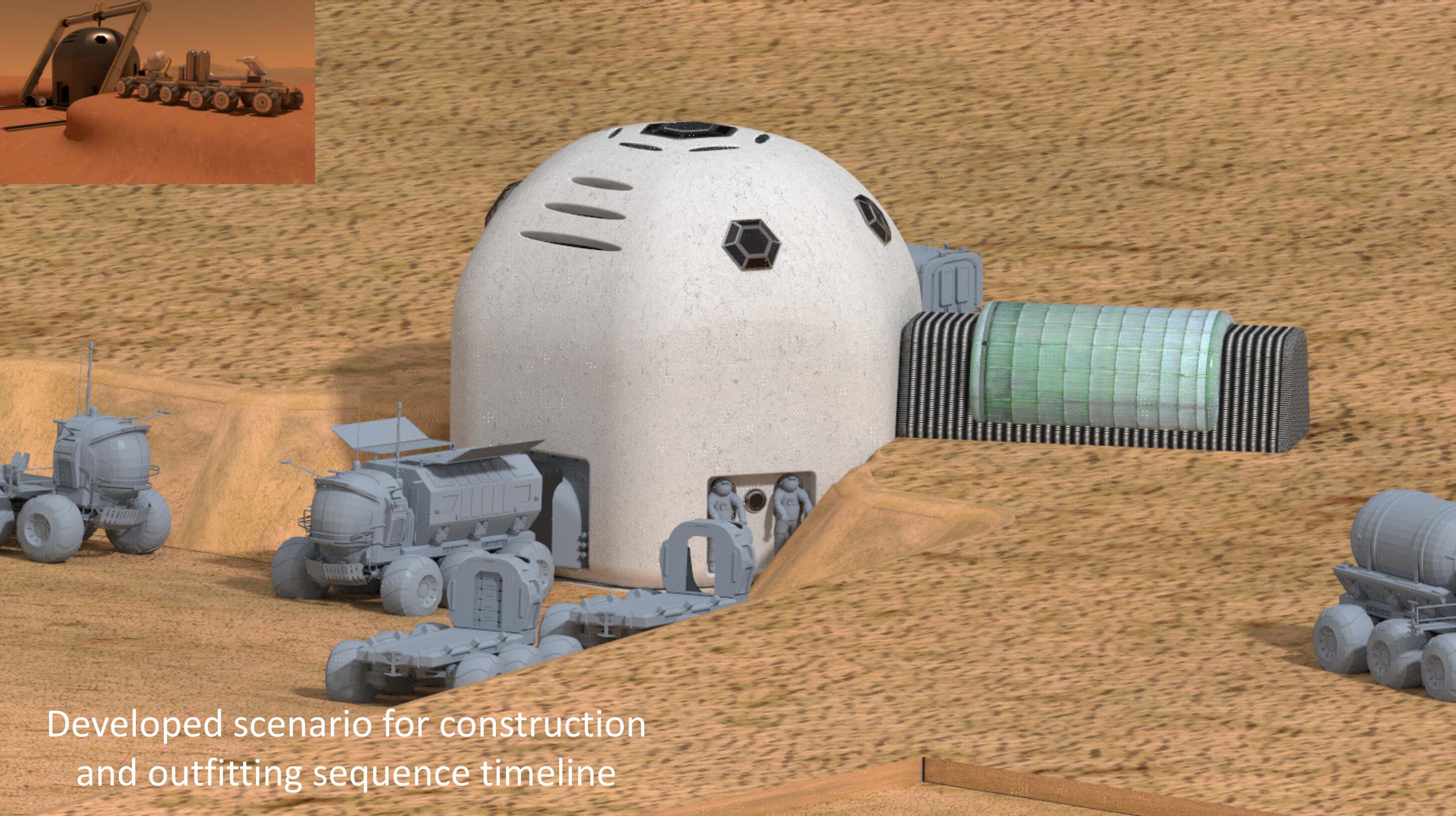
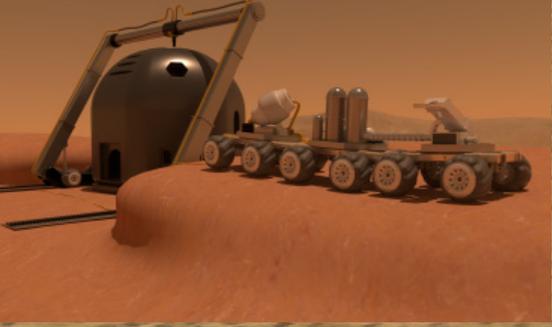
3-D Printed Planetary Habitat for Additive Construction Technology



Team X-Arc entry in NASA's Centennial Challenge 3D Printed Mars Habitat Competition
(Placed 4th out of 17 contestants)



Required 100% design for
structural and outfitting systems



Developed scenario for construction
and outfitting sequence timeline

Construction and Outfitting Sequence Timeline Video

(2:30 min)



Total Estimated Construction Time

Excavation Start to Outfitting Complete

Phase	Sols
EXCAVATION	20.3 sols
PRINT	17.5 sols
BACKFILL	11.2 sols
OUTFITTING (UNPRESSURIZED)	30.0 sols
OUTFITTING (PRESURRIZED)	30.0 sols
TOTAL	109 sols (112 days) minimum to +/-157.2 sols (+/-161.2 days)

Excavation Timeline

- The volume of regolith to be excavated for habitat printing is 20 meters square by 2.5 meters deep with an access ramp that fans out to 40 meters wide at the surface elevation over a 40 meter length.
- This is $20 \times 20 \times 2.5 + 20 \times 40 \times 2.5 \times 0.5 + 2 \times 10 \times 40 \times 2.5 \times 0.5 = 1000 + 1000 + 1000 = \underline{3000}$ cubic meters.
- With two scrapers removing 3 cubic meters per hour each, it will take 500 hours to excavate the habitat site. This is 20.3 sols at continuous operation or 30 sols operating 67.7% of the time.

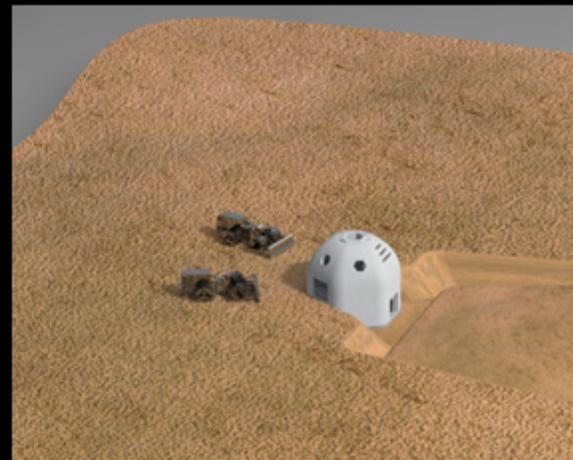


Print Timeline

- Habitat printing time is based on the same printing rate required to create our 1/3 scale habitat in 30 hours (600 kg/hr)
- Mass flow rates equate to 203,218 cc/hr
- Our new wall cross section design average density is 53% of the our previous Phase 3, Level 1 wall design
 - It has two 10 cm solid inner and outer bands with a 70% hollow/30% solid middle band, (instead of the previous solid 60 cm thick solid wall), to decrease thermal conductivity
- This reduces printed material volume from 164.42 m³ to 87.7 m³.
- We estimate the print time to be 17.5 to 32.9 sols operating around the clock as actual wall material density increases from 53% to 100% at habitat base and apex.
 - At 50% printer up time, it will take 35 to 65.7 sols to print each habitat.

Backfill & Leveling Timeline

- Backfilling the excavated area after printing the habit requires filling in a volume that is 7.5 x 20 x 2.5 meters, or 375 cubic meters
- At 2 cubic meter per hour, this will take 11.2 sols operating 67.7% of the time
 - Reduced rate relative to excavating is allowed for packing and tamping.



Outfitting Timeline

- Un-pressurized and pressurized outfitting sequences are robotic and crew assisted



- We allow 30 sols to move all interior large secondary structure and outfitting items before sealing and pressurization:
 - Largest bulk items include: two airlocks, one greenhouse hatch door; two suit port stands; four hexagonal cupolas, six ellipsoidal windows, the apex window; four crew quarter paneling assemblies; floor panels for three floor systems; and the elevator
 - Airlock openings are installed last
- Another 30 sols is allowed to install additional interior secondary structures and outfitting furnishings after pressurization

