



Daring you to ask

What if?

Centennial Challenges

Monsi Roman, Program Manager

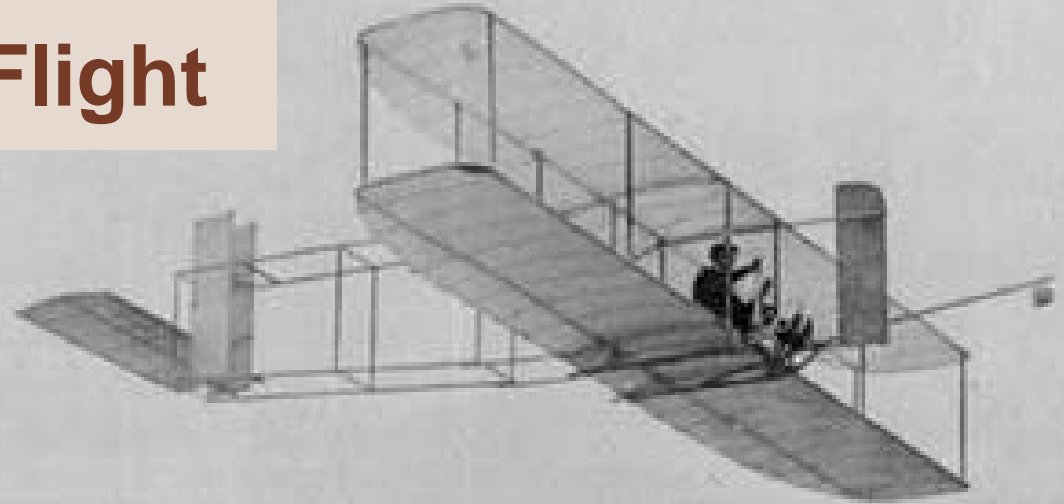
Tracie Prater, Subject Matter Expert for 3D-Printed
Habitat Challenge



Why Centennial Challenges?

- The program was established to conduct prize competitions in support of the Vision for Space Exploration and ongoing NASA programs
- Although the first competition was started in 2005, development of the program started in 2003 to commemorate ...

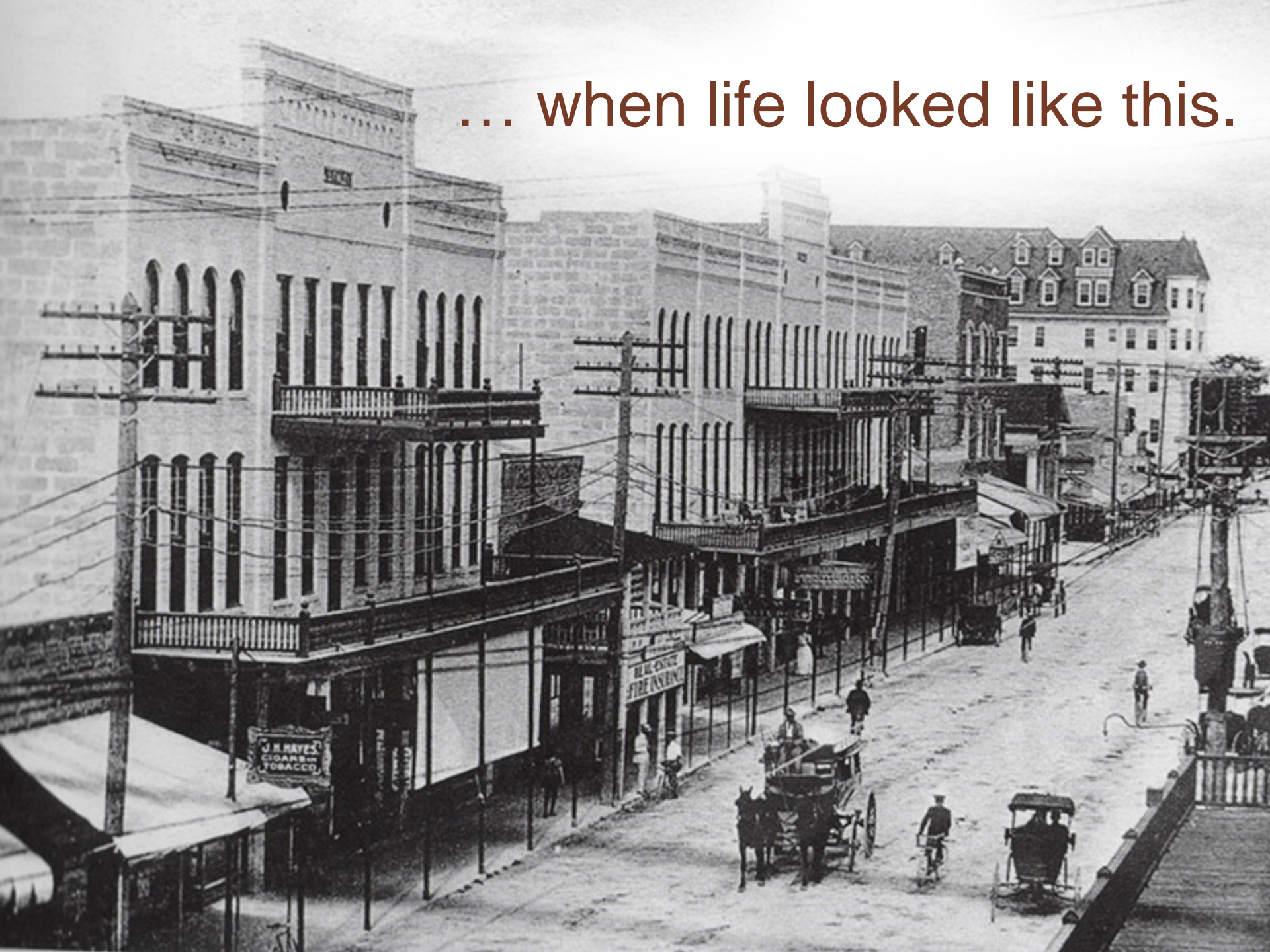
The Centennial of Flight



The Wright “Flyer”

An aircraft built of wood, powered by hand made propellers flew at Kitty Hawk, North Carolina, on December 17, 1903, making a 12-second flight.

... when life looked like this.



At the turn of the century, it was probably hard to imagine this ...



In the early 1900s, brothers and bicycle builders Wilbur and Orville Wright revolutionized the world with the first successful airplane.

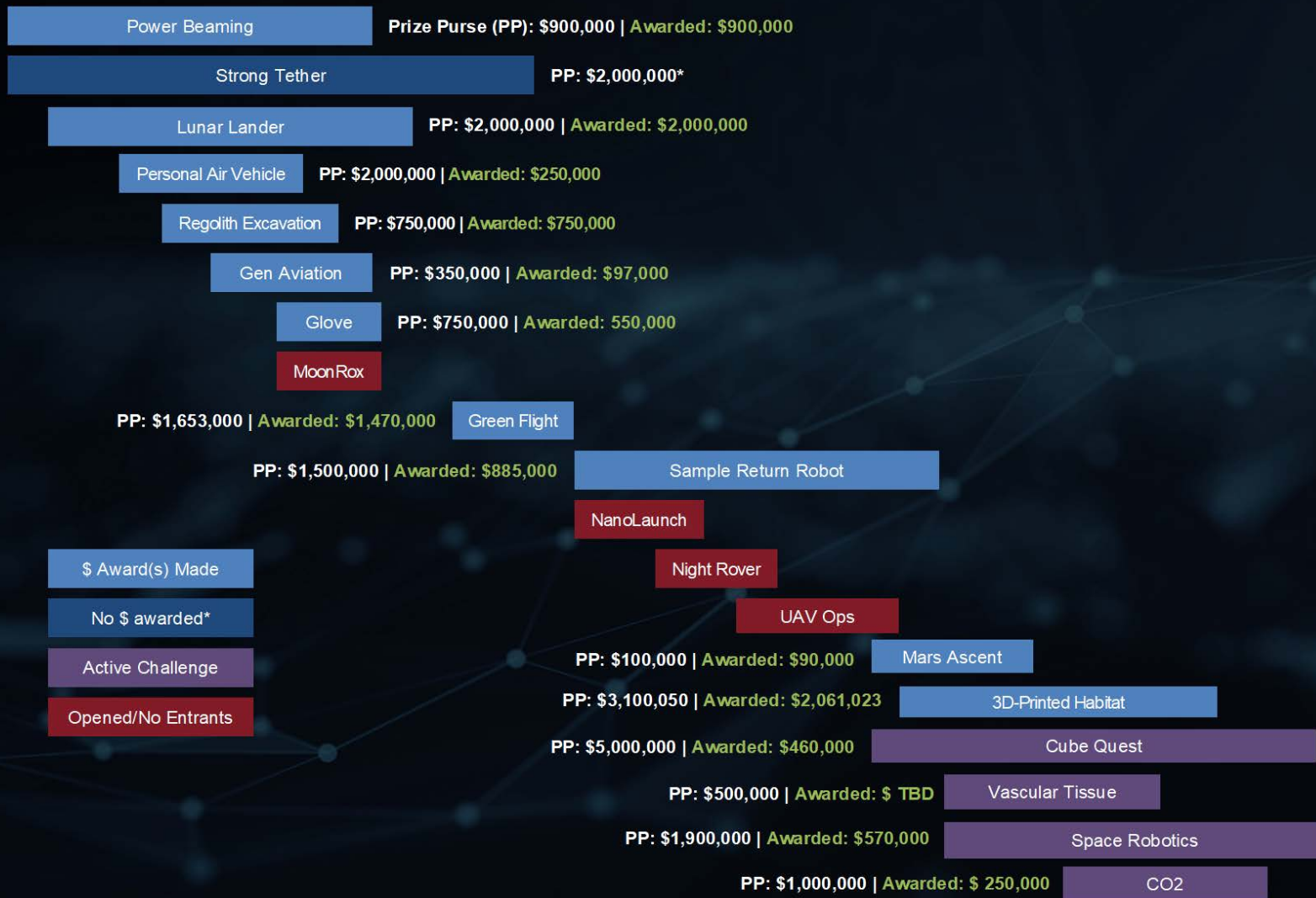


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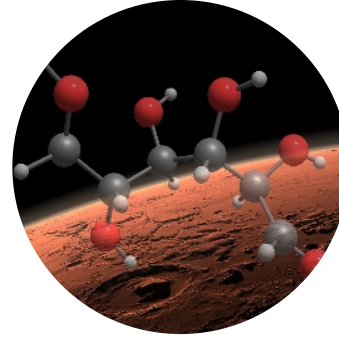
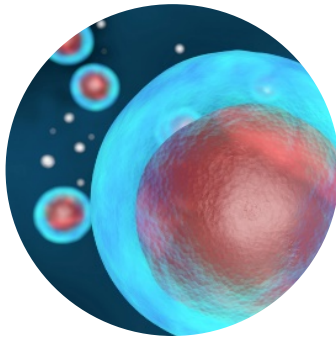
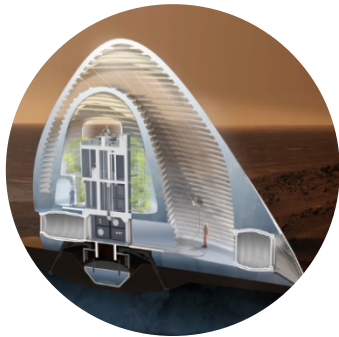
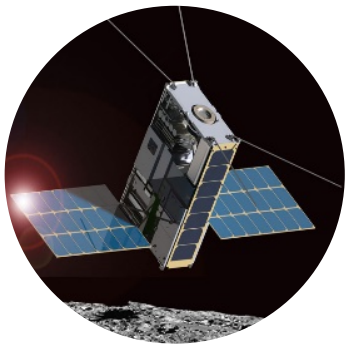


Summary of Program Competitions (2005–2018)

2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023



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5 Active Competitions

What if a
long-distance call
could reach a
new world?



A detailed illustration of a Mars rover, likely a Curiosity rover, positioned on a rocky, orange-hued landscape. The rover is shown from a side-rear perspective, highlighting its six large, treaded wheels and its complex mechanical structure. The background features rolling hills and a hazy, orange sky, characteristic of the Martian environment. The rover's mast is raised, and its robotic arm is extended towards a large rock in the foreground.

What if your
coworkers came
with **batteries?**

What if creating
a new material
started with a
single breath?





What if space held
the key to
better health?

What will home
look like ...

on Mars?





Competition Vision

- Advance the automated manufacturing and materials technologies needed for fabrication of habitats on a planetary surface using indigenous materials and mission recyclables
- Terrestrially, these technologies stand to revolutionize the construction industry by automating labor intensive processes and enabling rapid fabrication of large scale structures
 - World's population will increase from 6.6 billion to 12.9 billion by 2100
 - Requires aggressive construction practices to satisfy increased demand for housing
 - Other applications: disaster response, military field operations
- **3D Printing:** process of constructing a 3D object by depositing material layer by layer based on a digital part file
 - removes some design constraints (“manufacturing for design”)
 - enables building and testing earlier in project lifecycle
 - ability to work with new material formulations and maximize use of in situ resources (planetary surface construction applications)



2nd Place
Team Gamma



1st Place
SEArch/Clouds Architecture Office

3rd Place
Lava Hive

3DPH Challenge Phase 1: Design
7/2015- 9/2015
Prize Purse: \$50,000/\$40,000 awarded

Develop state-of-the-art architectural concepts that take advantage of the unique capabilities offered by 3D printing.

3DPH Challenge Phase 2: Material
6/2016- 5/2017

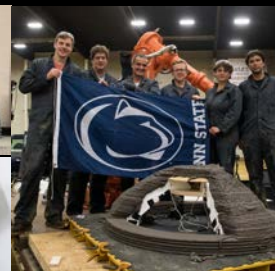
Prize Purse: \$1,100,000/\$701,000 awarded

Autonomously 3D Print structural components using indigenous materials and recyclables.

Level 1



Level 2



2nd Place
Penn State

Level 3



1st Place
Branch Technologies

Level 4: Virtual Construction (Building Information Model/BIM)



2nd place
Zopherus

1st Place
SEArch+ / Apis Cor

3rd place
Mars Incubator

3DPH Challenge Phase 3: Build it
11/2017- 5/2019
Prize Purse: \$2,000,000/\$1,320,000 awarded

Level 4: Develop a Building Information Model (BIM) for a habitat.
Level 5: Demonstrate an autonomous additive manufacturing system to create a 1/3 scale habitat.

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Phase II Competition: Materials

- One objective of competition is creation of construction materials from indigenous materials and mission waste (polymer recyclables which would otherwise be “nuisance” materials)
- Sliding materials scale rates material based on relevance to planetary missions

Material Applicability	Least Relevant							Most Relevant		
Fine Rock Aggregate ($< \frac{1}{4}$ " mean particle diameter)		MR		IRS		CSR		GSS	BSR	CBI
Coarse Rock Aggregate ($> \frac{1}{4}$ " mean particle diameter)	MR		IRS		CSR		GSS	BSR	CBI	
Trash Recyclables	VY	PS	AF		PP	NY		PT	HP	LP
3DP Factor	1	2	3	4	5	6	7	8	9	10

Scoring Rewards Planetary and Mission Recyclable Materials Relevance

CBI - Crushed basaltic igneous rock (SiO₂ weight percent less than or equal to 57)
 BSR - Basaltic sedimentary rocks (talus, alluvium with very little alteration/weathering, or mine tailings)
 GSS - Gypsum sand and siliceous sedimentary rocks (e.g., sand box sand, mudstone)
 CSR - Carbonaceous sedimentary rocks (e.g., limestone, dolomite)
 IRS - Igneous rocks with SiO₂ weight percent greater than 57 (e.g., granite)
 MR - Metamorphic rocks (e.g., slate)

LP - LDPE polyethylene (#4 recycle code)
 HP - HDPE polyethylene (#2 recycle code)
 PT - Polyethylene Terephthalate (#1 recycle code)
 NY - Nylon (#7 recycle code)
 PP - Polypropylene (#5 recycle code)
 AF - Aluminum foil or ground up aluminum parts
 PS - Polystyrene (#6 recycle code)
 VY - Vinyl (#3 recycle code)



Basalt rock



Phase II Competition: Results



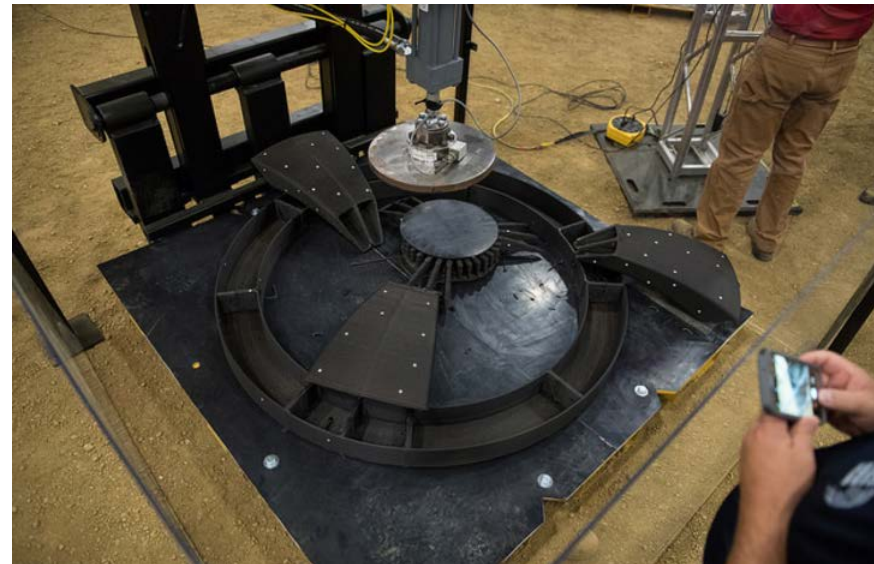
Winning level 1 entry
(compression specimen)
from Foster + Partners and
Branch Technology



Second-place team Form
Forge of Oregon State
University, Corvallis, printed
this beam for the phase II,
level 2 challenge. Image
courtesy Form Forge.

Winning material from phase II developed by Techmer PM for Branch Technology and Foster+Partners (blend of rock-based material and recyclable polymer)¹:

- beam held 32,500 lbs. in a three-point bending test
- cylinder held 27,450 pounds in compression
- dome held 3,726 pounds ultimate load



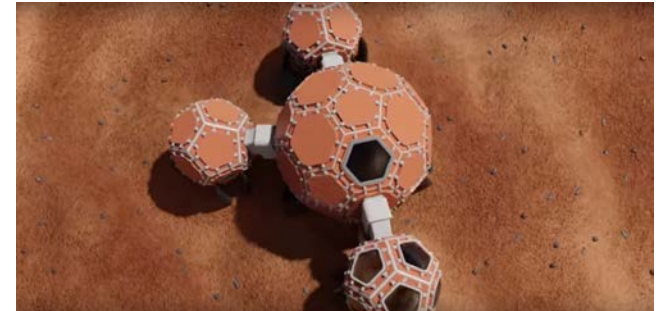
Crush test of winning dome structure from Foster + Partners and Branch Technology at level 3 head to head

1. Techmer PM press release: <https://www.techmerpm.com/2017/08/29/branch-technology-and-foster-partners-win-first-prize-in-nasas-3-d-printed-habitat-challenge-using-materials-designed-by-techmer-pm/>



Phase III Competition: Virtual Construction (Level 4)

Focused on Building Information Modeling (BIM): 3D-model must have 100% of the information required to build the structure



Team Zopherus:

- Lander structure encloses the printer
- Lander provides a pressurized, thermally controlled print environment for processing of the extracted materials into feedstock and fabrication of the first habitat module
- Lander traverses across the surface to build other modules

Team AI.Space Factory:

- Vertically oriented cylinder made of PLA reinforced with basalt fiber
- cylindrical geometry was chosen to maximize the ratio of usable living space to surface area and reduce structural stresses
- A double shell structure allows for expansion and contraction of material with the thermal swings the structure will experience

Team Mars Incubator:

- Modular habitat design
- External support structures formed by laser melting of basalt fiber
- Panels of habitat made from regolith and polyethylene reinforced with basalt fiber
- Panels are robotically placed and tensioning device cinches anchor points



Phase III Competition: Construction

AI. Space Factory (New York City, NY)



Pennsylvania State University (University Park)

- 30 hours to print 1/3 scale habitat at head to head competition at Caterpillar Edwards for level 5
- Emphasis on autonomy: scoring penalties imposed for interventions during printing (remote and physical), teams also had to perform automated placement of three penetrations
- Three 3D-printed beams tested on site to evaluate material strength
- Previous levels included 3D printing of a foundation and habitat element with hydrostatic test

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Phase III Competition: Onsite Testing for Level 5

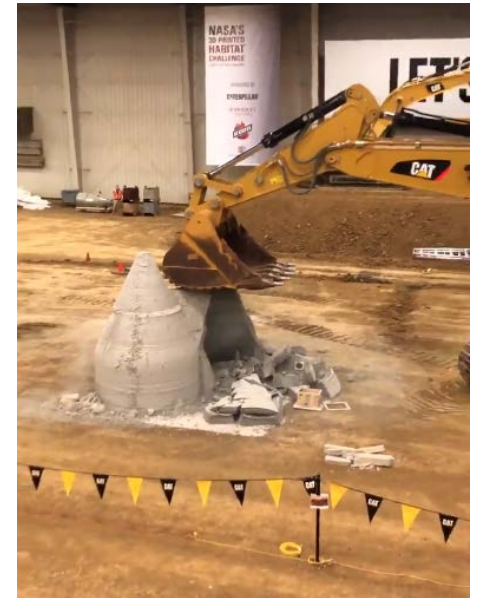
Tests of printed habitat included:



Smoke test: introduce smoke at a nominal low pressure to qualitatively assess the air-tightness of the habitat.



Impact test: select a vulnerable location on the habitat structure to impact with iron balls released from different heights to simulate meteoroid debris.



Crush test: Habitats subjected to a crushing force applied by a large hydraulic excavator bucket.

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Phase III Competition: Level 5 Results



**1st Place: AI. Space Factory (New York City, NY):
\$500,000 in prize money**



**2nd place: Pennsylvania State University (University
Park), \$200,000 in prize money**



Questions?



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