Daring you to ask

What if?

Centennial Challenges

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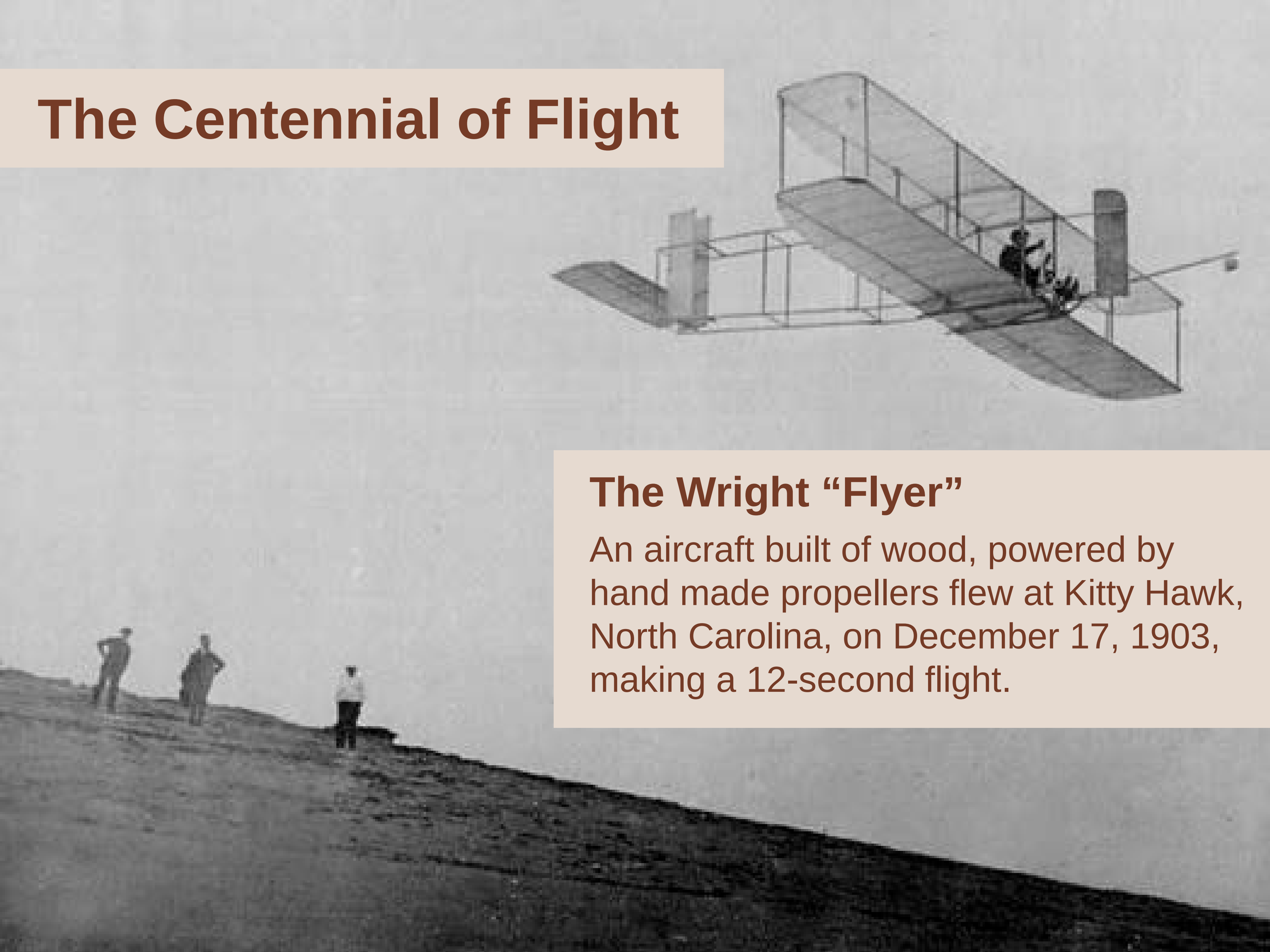
Why Centennial Challenges?

- 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 …

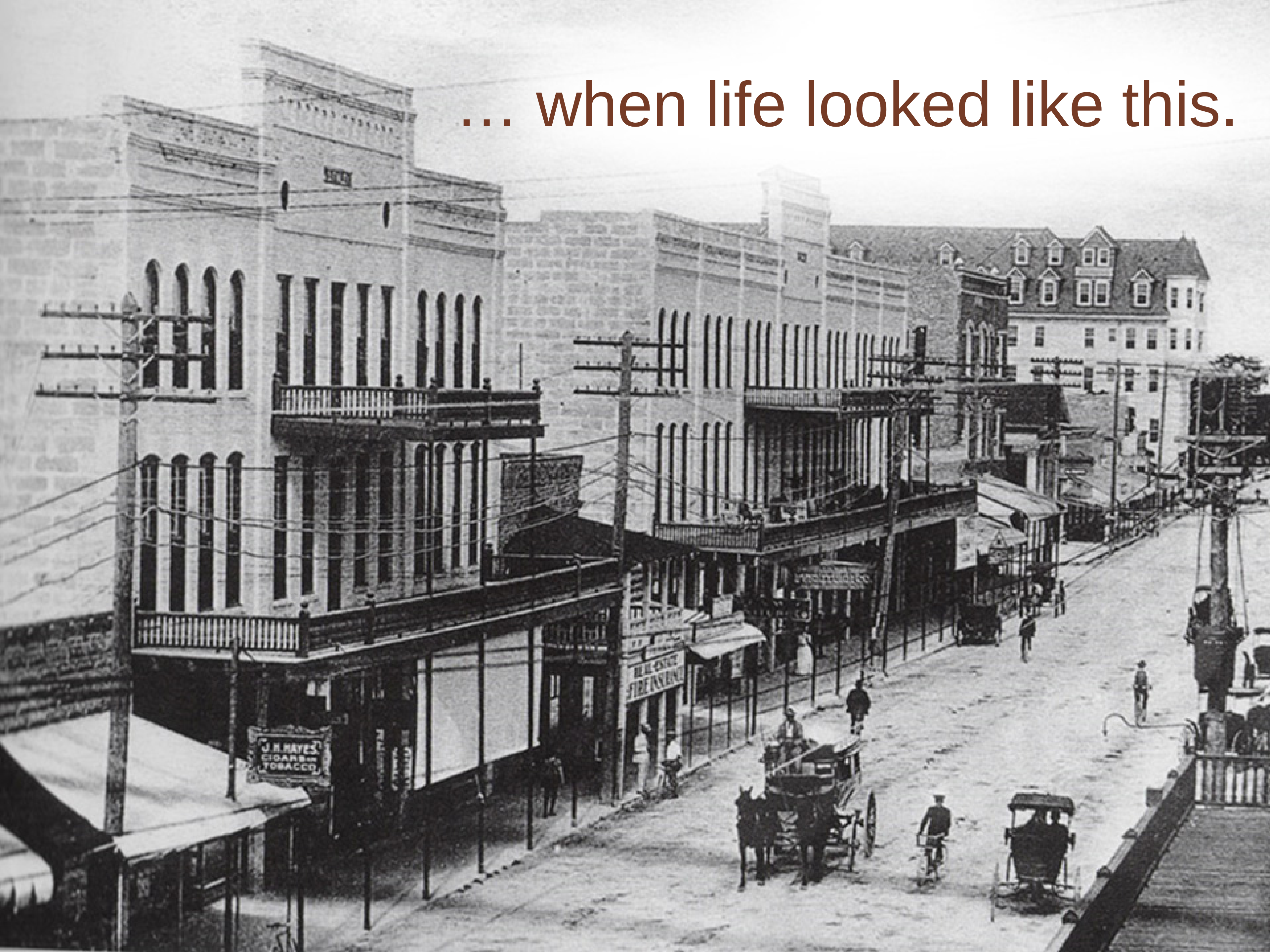
The Centennial of Flight



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.

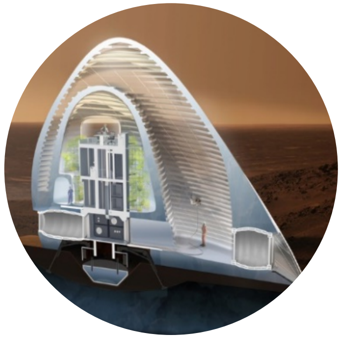


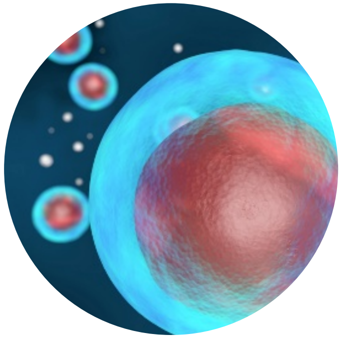

At the turn of the century, it was probably hard to imagine this …

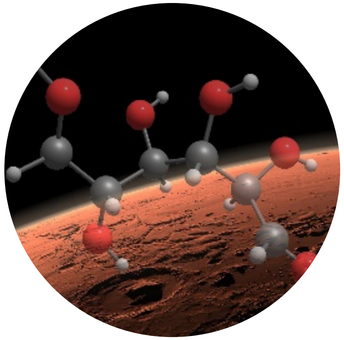
In the early 1900s, brothers and bicycle builders Wilbur and Orville Wright revolutionized the world with the first successful airplane.

centennialchallenges

Summary of Program Competitions (2005–2018)







5 Active Competitions


What if a long-distance call could reach a new world?
www.nasa.gov/cubequest


What if your coworkers came with batteries?
www.nasa.gov/spacebot


What if creating
a new material
started with a
single breath?
www.nasa.gov/co2challenge


What if space held
the key to
better health?
www.nasa.gov/**tissueprize**


What will home look like …
on Mars?
www.nasa.gov/3DPHab

Competition Vision

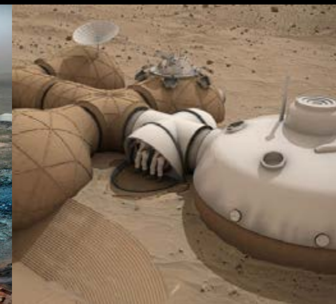
- Advance the automated manufacturing and materials technologies needed for fabrication of habitats on a planetary surface using indigenous materials and mission recyclables

- 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.

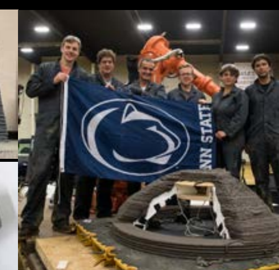
3DPH Challenge Phase 2: Material
6/2016- 5/2017
Prize Purse: $1,100,000/$701,000 awarded

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

Level 1

Level 2

Level 3



2nd Place
Penn State

1st Place
Branch Technologies

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

1st Place
SEArch+ / Apis Cor

2nd place
Zopherus

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.

Phase II Competition: Materials

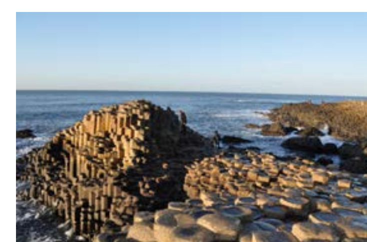
- One objective of competition is creation of construction materials from indigenous materials and mission waste (polymer recyclables which would otherwise be “nuisance” materials)
- Sliding materials scale rates material based on relevance to planetary missions

Material Applicability	Least Relevant								Most Relevant	
Fine Rock Aggregate (< ¼” mean particle diameter)		MR		IRS		CSR		GSS	BSR	CBI
Coarse Rock Aggregate (> ¼” 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 (SiO_2 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 SiO_2 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

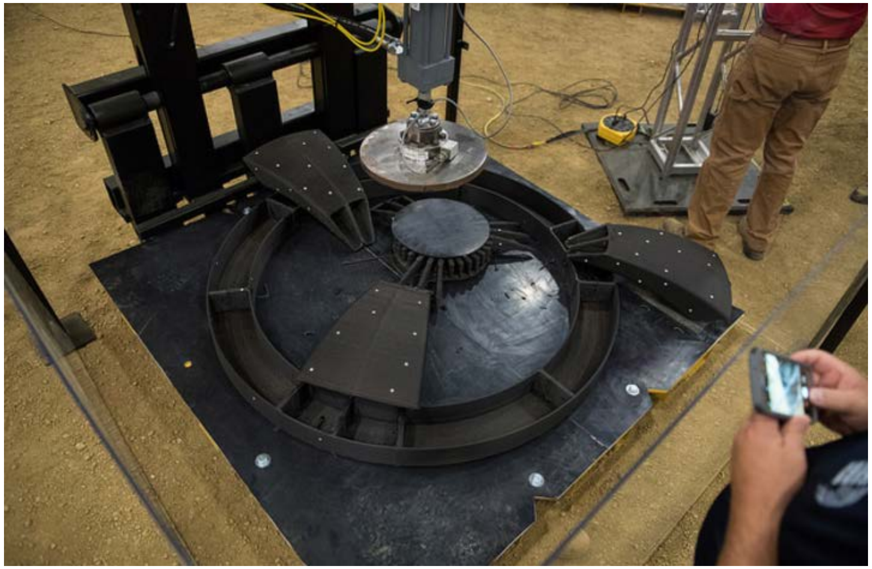
Phase II Competition: Results

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

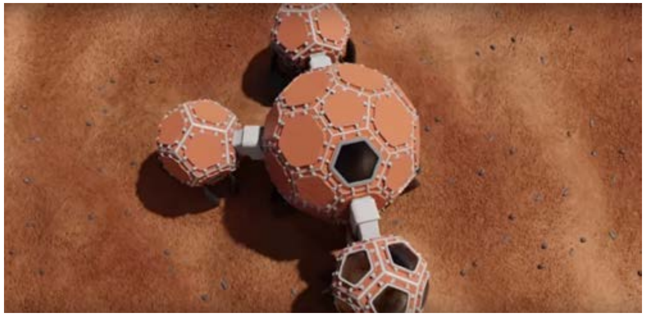


Crush test of winning dome structure from Foster + Partners and Branch Technology at level 3 head to head

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

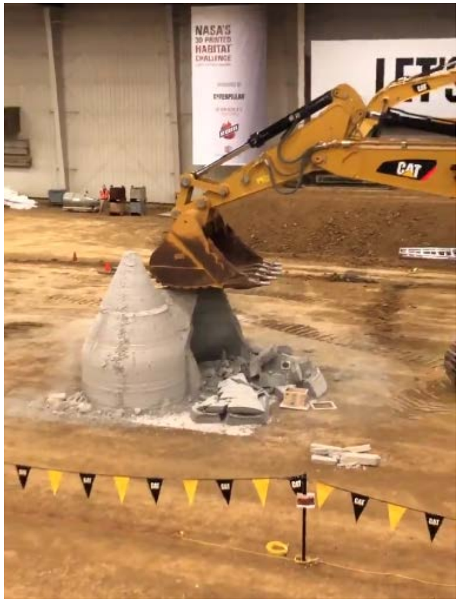
AI. Space Factory (New York City, NY)

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

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.

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 centennial**challenges**

Questions?

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