

In-space Manufacturing (ISM): Make it, Don't Take it!

Niki Werkheiser

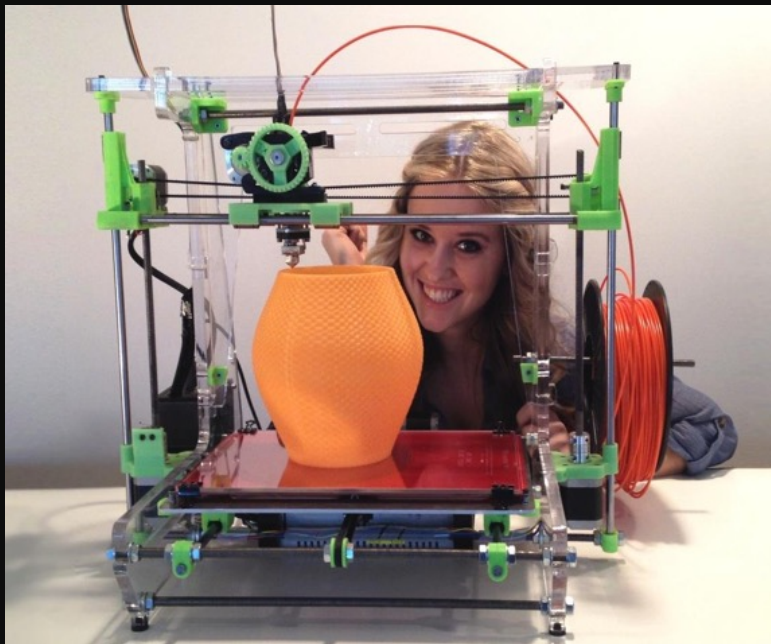
NASA In-Space Manufacturing, Manager



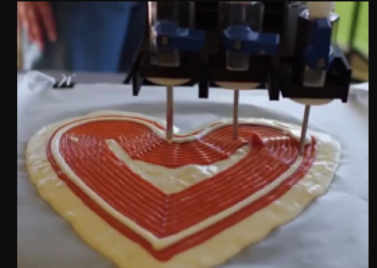
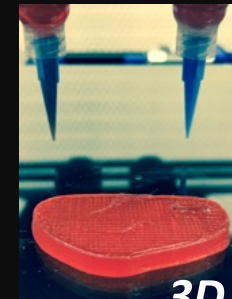
***Future of Space Exploration Panel
Huntsville Public Library
March 21, 2019***

What is 3D Printing?

A 3D printer works a lot like the printers that print out images on paper in two-dimensions, except a 3D Printer actually 'prints' three-dimensional objects by layering melted plastic or metals based on the electronic models (i.e. 'instructions') sent to the machine.



Oak Ridge National Labs 3D Printed Car



3D Printed Food



Prosthetics



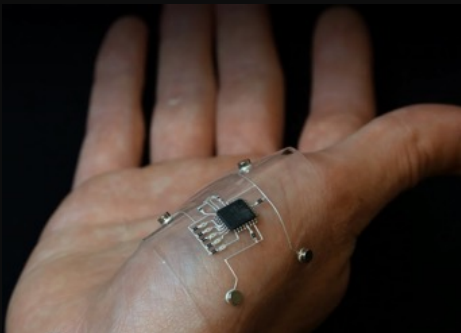
New Balance 3D Printed Shoes

What would YOU 3D Print?



Useful, custom tools

Flexible Electronics & Wearables



But, why does NASA need 3D Printing?

- *When we live on the Moon or Mars, we will be much further from earth than we are on the International Space Station (ISS) and our astronauts won't always be able to wait for a launch to replace consumables, perform maintenance, or fix a broken part.*
- *Remember, the ISS is ~250 miles from the earth and it only takes a few hours to launch there.*
- *The moon is ~240,000 miles away and takes around 3-4 days to get there from earth.*
- *The average distance of Mars from earth is ~140 MILLION miles away from earth (closest recorded approach in history was 34.8 million miles) and it will take several months to get there.*



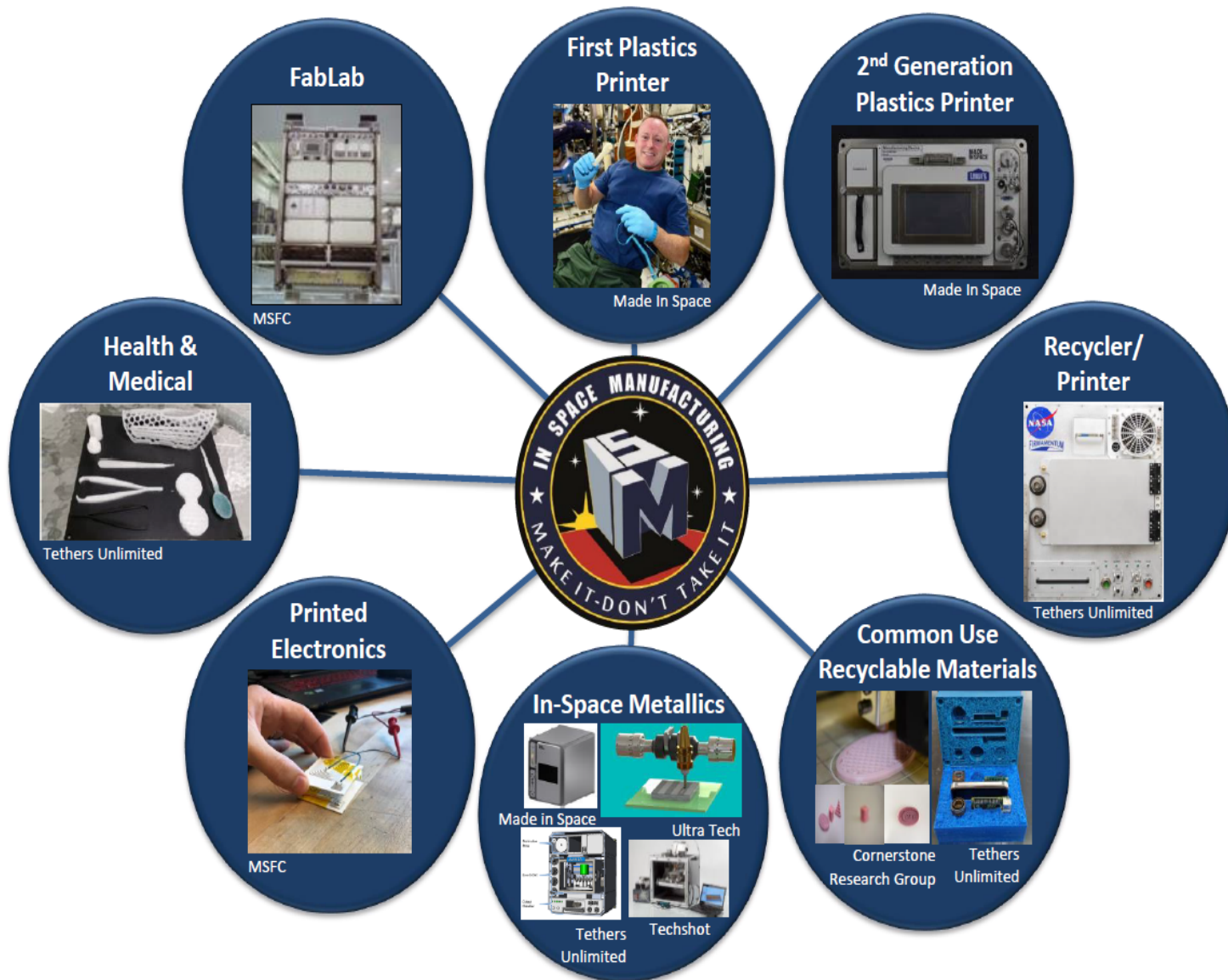
Current ISS Resupply Model...



One-of-a-kind Test-bed: The International Space Station (ISS)



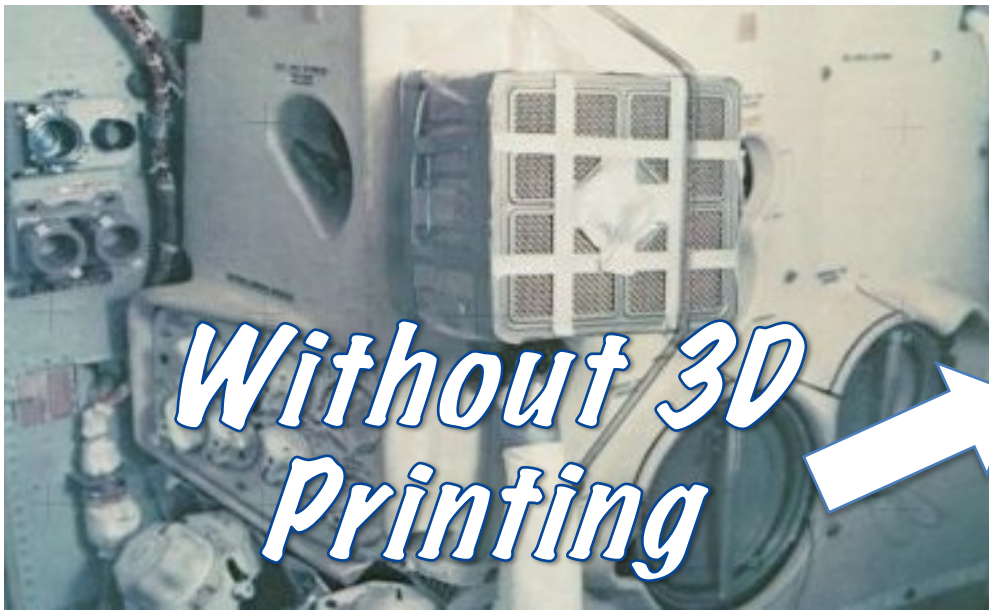
In-Space Manufacturing (ISM) Project... Make it, Don't Take it!



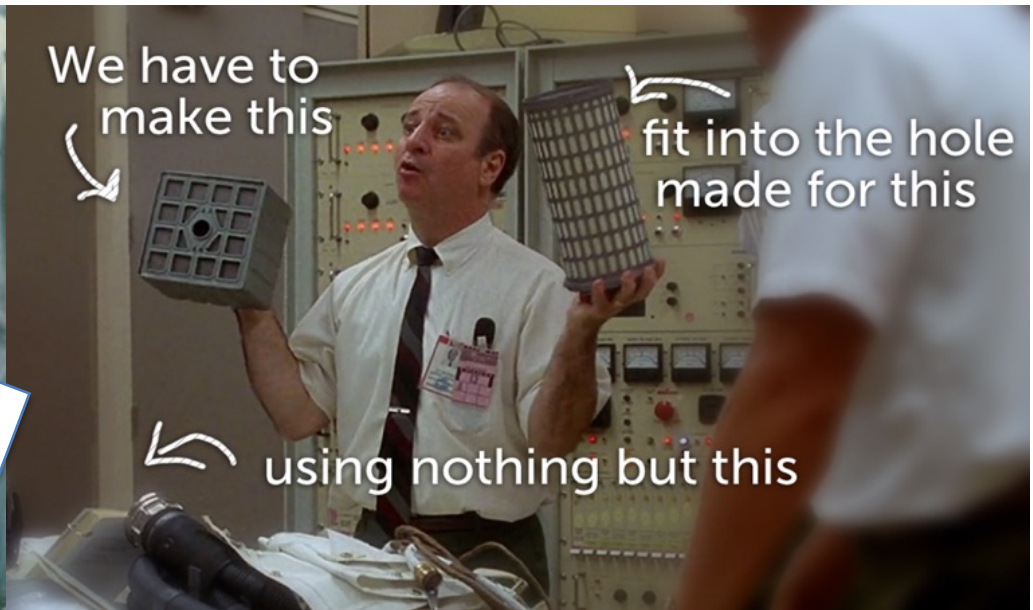
Objective:

To develop and demonstrate on-demand manufacturing, recycling, and repair capabilities for long-duration spaceflight missions.

- Replacement parts, repairs, new components from metals, plastics, electronics, and in-situ materials
- Recycling and reuse of waste materials & consumables



*Without 3D
Printing*

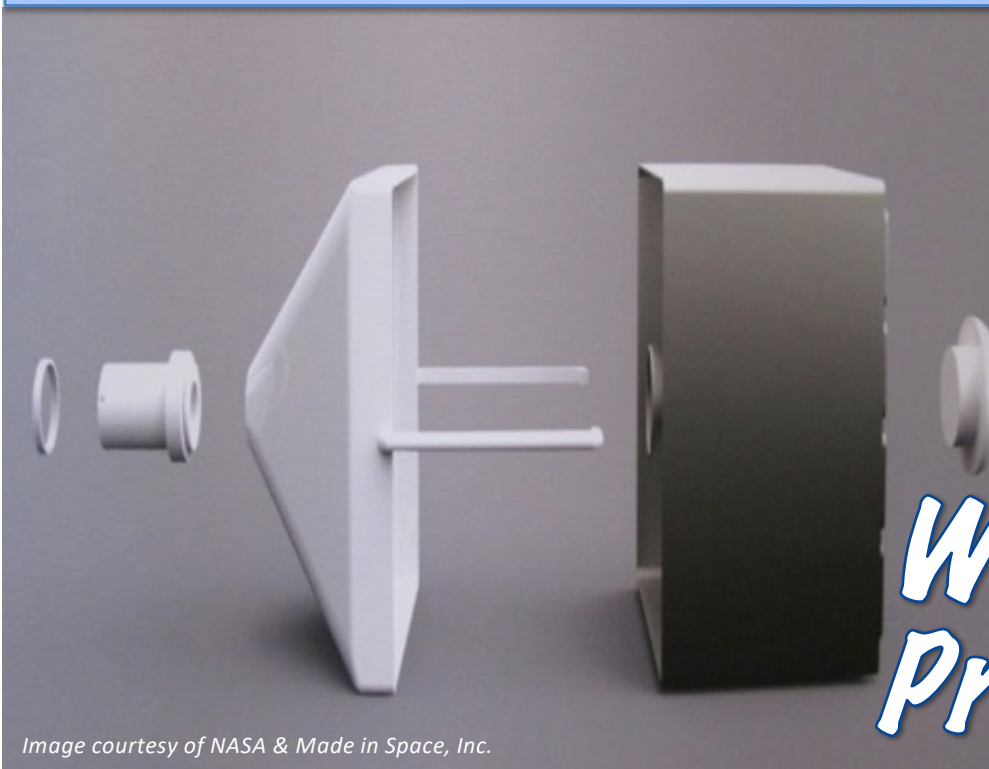


We have to
make this

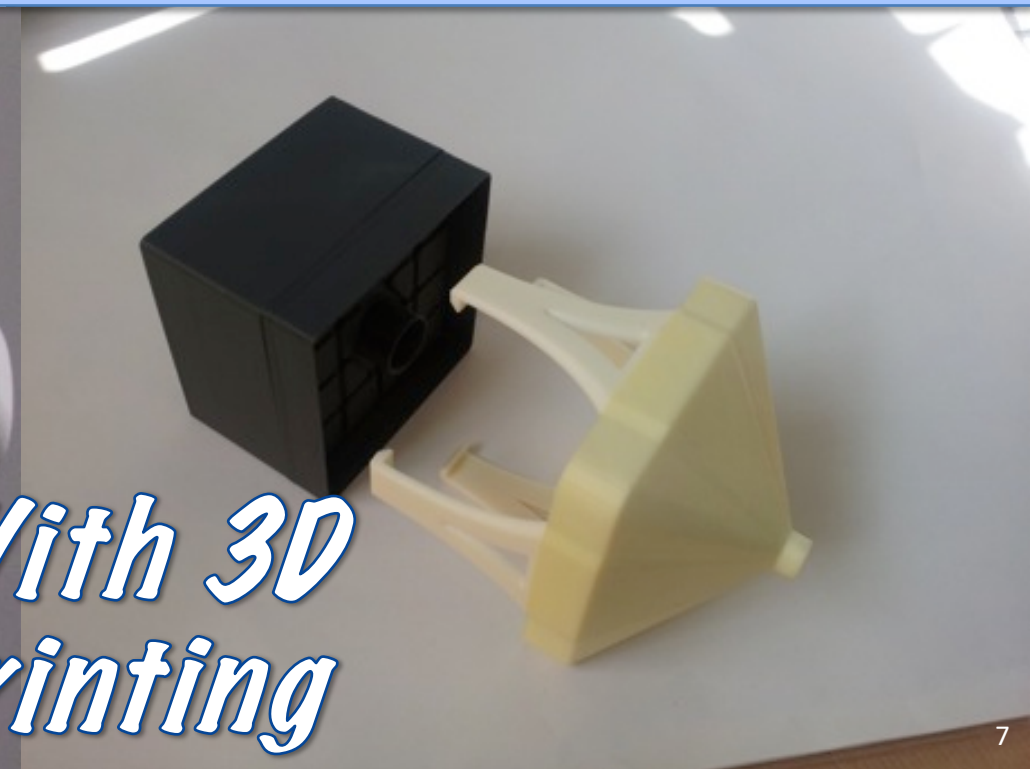
fit into the hole
made for this

using nothing but this

Square peg in Round Hole? No problem!



*With 3D
Printing*



First Step: Does 3D Printing Work in Space?

- *In 2014, NASA and the company Made in Space, Inc. (MIS) sent the first 3D Printer to the International Space Station (ISS) to see if it worked the same in microgravity as it does on Earth.*
- *There were 55 parts printed on ISS and then returned to Earth where scientists and engineers at NASA tested and analyzed them to compare them to the ground samples.*
- *It was determined that you can 3D print plastic parts in space the same way that you do on Earth.*



We even 'emailed' the first 3D Printed Wrench to space!



1. Design Part



2. Uplink to ISS



4. Make it on ISS



Captain 'Butch' Wilmore holding the first 3D Printed Wrench in Space on the ISS. The design file for the wrench was 'emailed' (i.e. uplinked) from the ground to the ISS.

And then...the Additive Manufacturing Facility (AMF) by Made in Space, Inc.



- The second 3D Printer, the Additive Manufacturing Facility (AMF), has been operating on the International Space Station (ISS) since 2016.
- This printer is owned and operated by Made in Space, Inc. through agreement with the ISS National Lab.
- NASA is one of the customers, as well as other government agencies, industry, and academia.
- AMF can print with three types of plastic: ABS, ULTEM and High-density Polyethylene.

Examples of Parts Manufactured on the ISS AMF



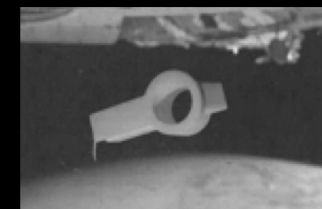
*SPHERES Free Flier Tow Hitch: This part joins two of the ISS free-fliers together in tandem
Printed 2/21/17*



*Radiation Enclosure Module (REM) printed in different thicknesses to hold monitors for radiation testing
Printed 3/20/17, 5/30/17, and 6/16/17*



*Antenna Feed Horn which is being tested with various printed coatings for in-space use
Printed 3/9/17 and returned on SpaceX-10 3/20/17*



*Oxygen Generation System (OGS) Adapter attaches over air to obtain a consistent and accurate reading of airflow through
Printed on 7/19/2016.*

Let's Talk Trash...

Did you know....on the International Space Station, astronauts currently squeeze their garbage into trash bags and, for temporary periods of time, store up to **2 metric tons** of trash on board before burning it up on re-entry!!

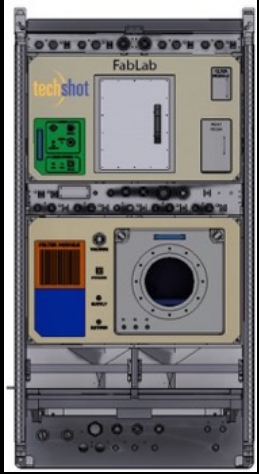


The Refabricator...3D Printer and Recycler in one package!!

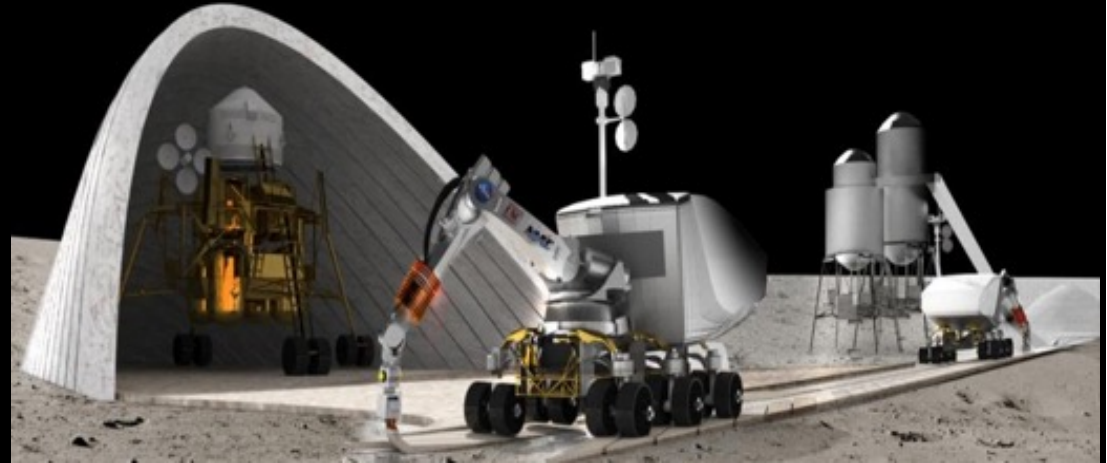
- The Refabricator launched to the ISS in November 2018 and is now installed on-orbit. It is the first ever integrated 3D Printer and Recycler. This means that it can recycle a 3D Printed Part back into filament (3D Printer 'ink') so you can make a brand new part.
- By recycling parts, NASA won't have to launch as much material or spare parts. We can even recycle plastic bags, packing foam, and food containers into new items!
- On Earth, this technology could use old water bottles and plastic bags from the grocery store to make filament to 3D print all kinds of things!



Stay Tuned - Coming to a Mission (not) Near You....

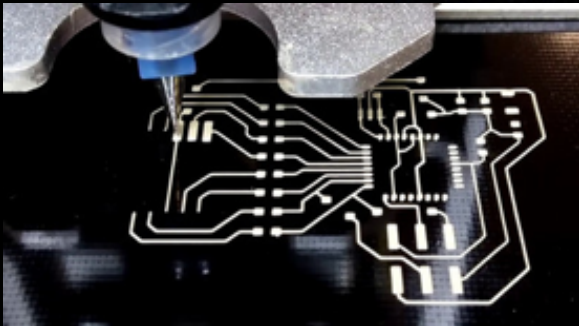


**The FabLab
Multi-
material
Printer for
Metals**



**Additive Construction
of Habitats Using In-
Situ Resources (i.e.
Moon or Mars 'Dirt')!!**

**3D Printed
Electronics
&
Wearables**



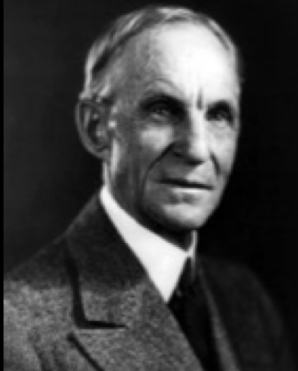
**Large
External
Structures
in Space**



My Favorite Part...QUESTIONS!!



*Tea.
Earl Grey.
Hot.*



“IF I HAD ASKED PEOPLE
WHAT THEY WANTED,
THEY WOULD HAVE SAID:
FASTER HORSES...”

Henry Ford

*“If what you’re doing is not seen by
some people as science fiction, it’s
probably not transformative
enough.” -Sergey Brin*