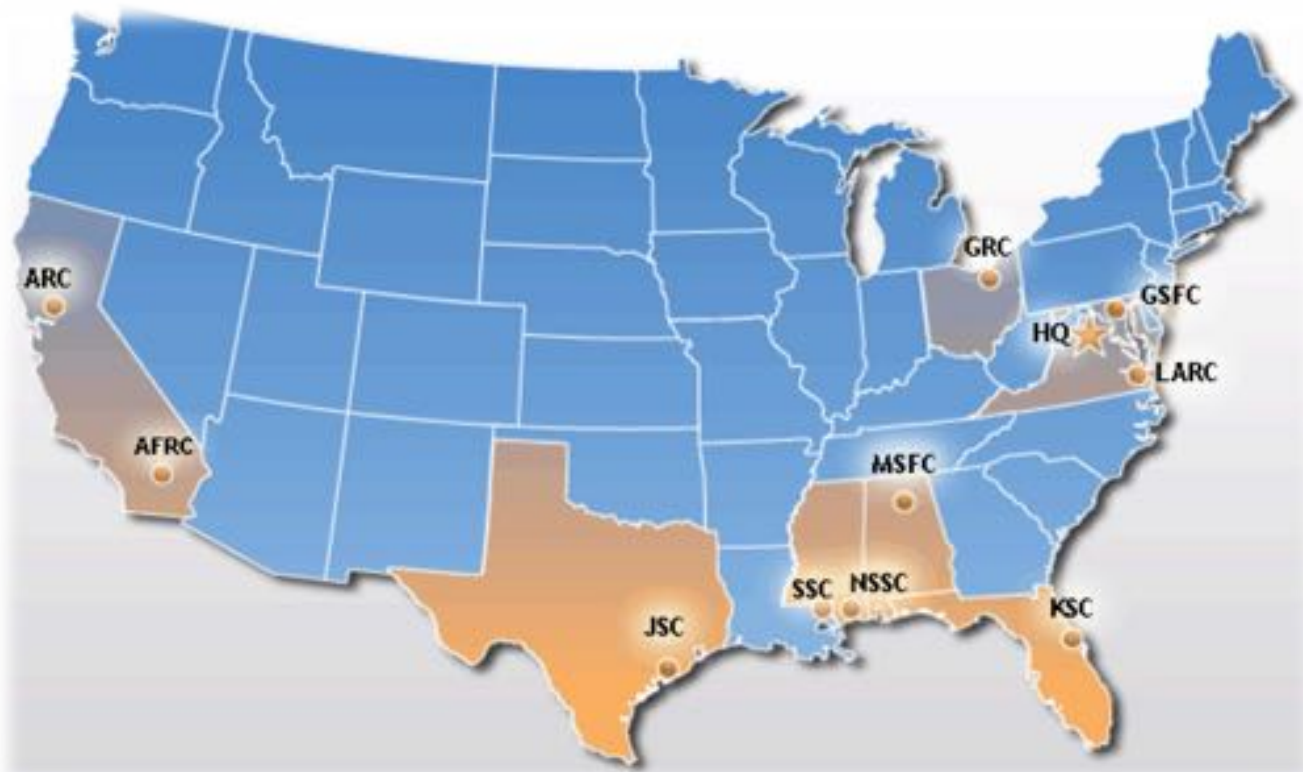




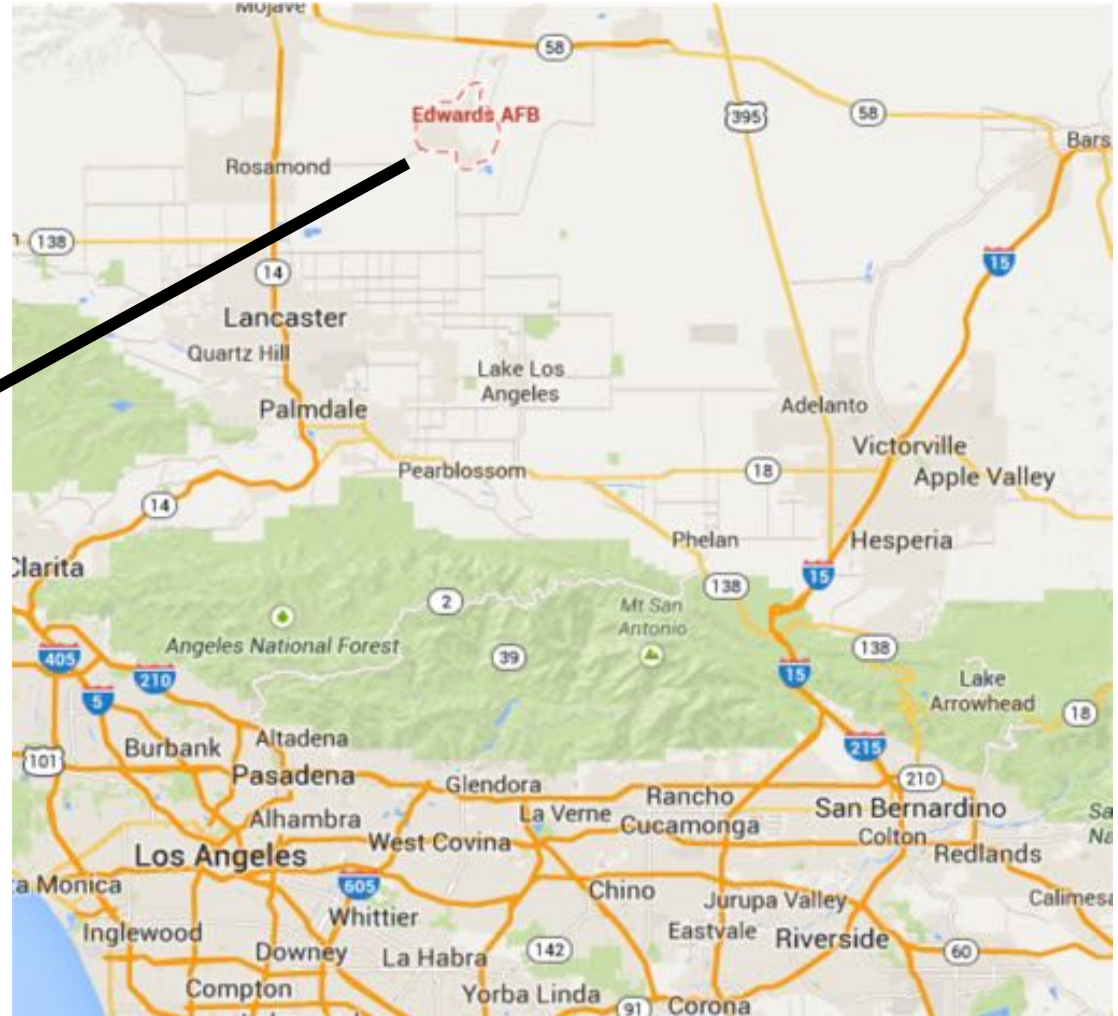
# Preliminary Research Aerodynamic Design to Land on Mars

David Berger

# About AFRC



# About AFRC



# My Background



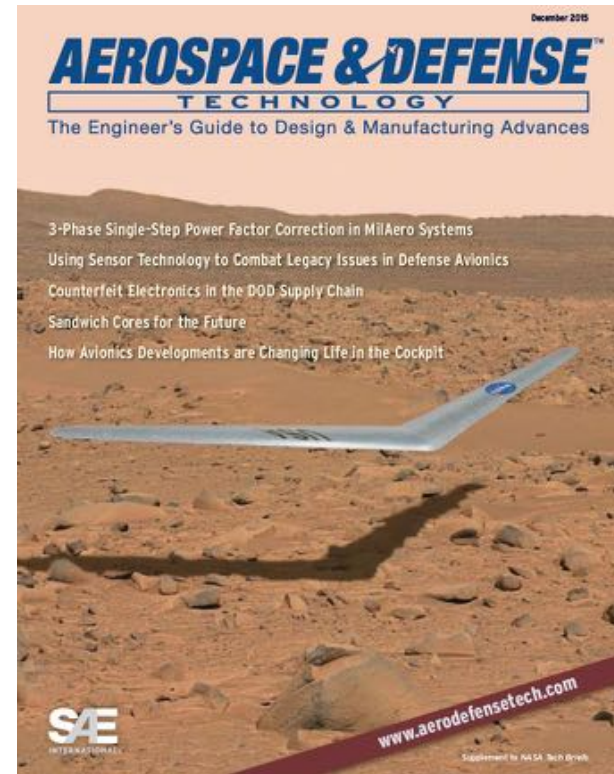
- High School US History Class-"The Right Stuff"
- Purdue Cooperative Education Program/Dryden
- Graduate School UMich/AFRL
- NASA Dryden
  - Propulsion Health Management and formation flight on C-17s
  - Systems Engineering
- NASA Johnson
  - Orion Vehicle-Exploration Flight Test 1

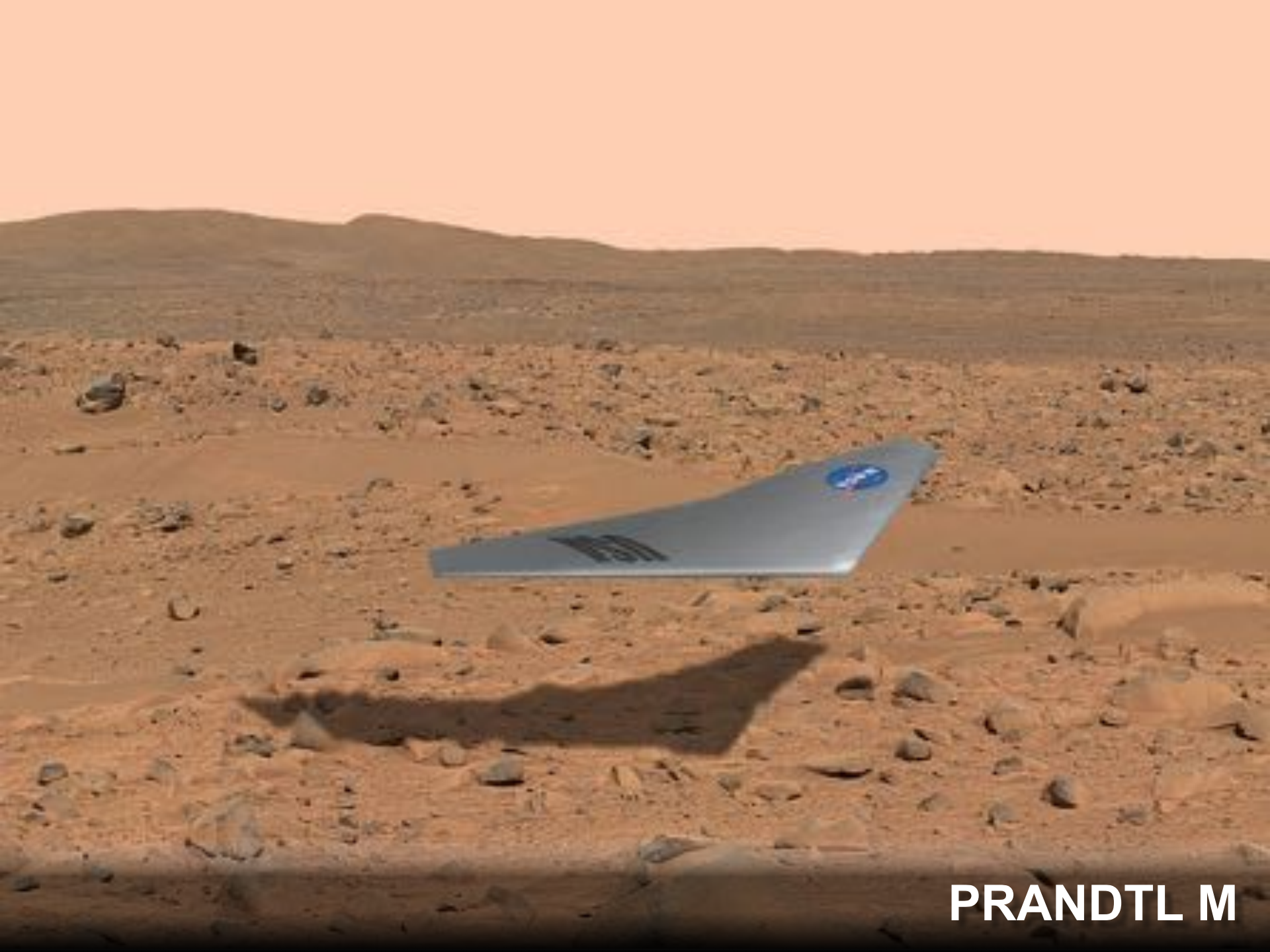


# Current Work



- University Affairs Officer for NASA Armstrong
- Preliminary AerodyNamic Design to Land on Mars (Prandtl-m)





**PRANDTL M**

# Prandtl-m Introduction



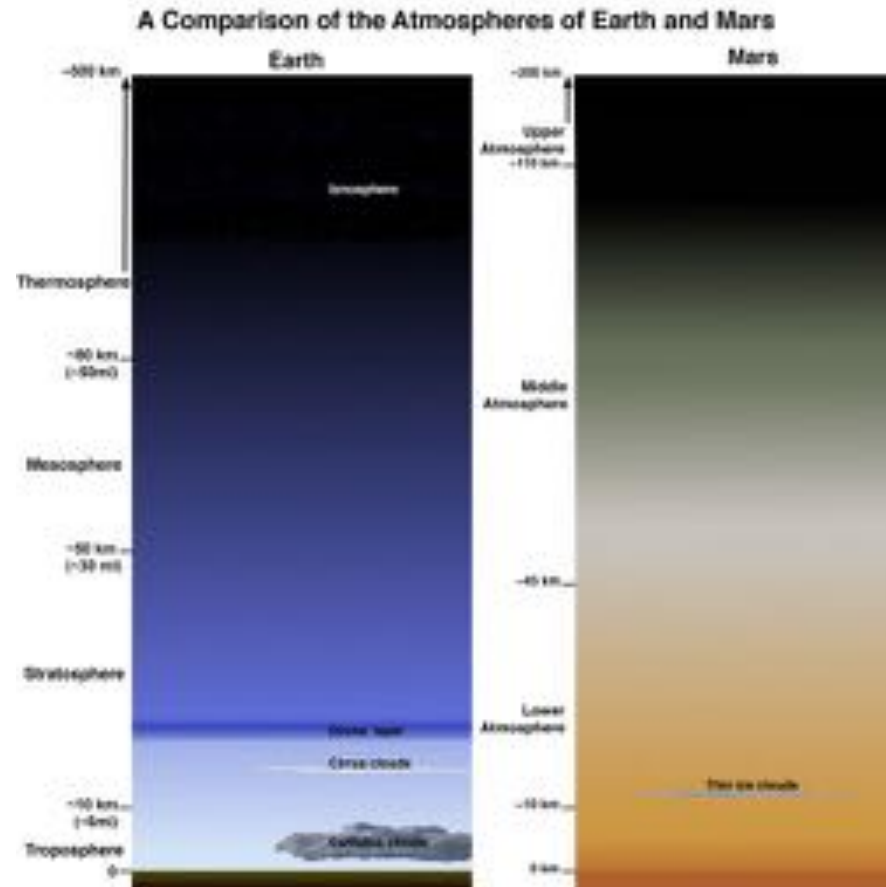
- A Mars aircraft can provide a new science and exploration platform capability
  - Direct atmospheric measurement
  - Higher resolution terrain mapping
  - Faster, longer range coverage than a rover
- Many previous Mars aircraft designs were large “flagship” missions
- Landing missions carry over 50kg of ballast for balance
- What if we replaced part of that with a 3U cubesat containing an airplane?
- What would a minimum viable Mars airplane look like?



# Prandtl-m Challenges



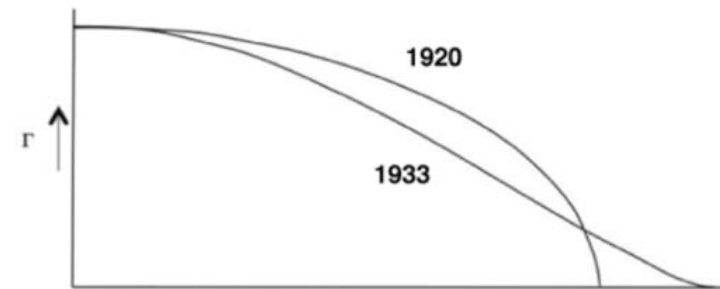
- Gravity: ~38% of Earth
- Atmosphere:
  - ~1% Density of Earth at sea level
  - Different chemical composition
  - Very cold <-30 C
- Aerodynamics
  - Very low Reynolds number
  - Moderate subsonic Mach number
- Avionics
  - Cold, low pressure environment
  - Radiation in transit and during flight
- Navigation:
  - No GPS
  - Weak magnetic field
- Size and Weight Constraints



# Prandtl-m Design Approach



- Question everything, all features must be justified and “buy” their way onto the vehicle
- Use Prandtl bell shaped lift distribution
  - Simplify configuration, increase reliability at deployment
  - Minimize volume and weight constraints
  - Increase stability and control
  - Increase range for data gathering
- Need sufficient chord to increase Reynolds number to ensure attached flow and remain subsonic



# Prandtl-m Project Approach



- Establish a build up approach and set up key proof of concepts tests and demonstrations
- Use all available tools available at the appropriate time (work from low fidelity to high fidelity)
- Rely on partner expertise
- Iterate quickly
- Use existing tools/hardware when possible
- Test, test, and test again

# Prandtl-m Design Process Example



1. New vehicle configuration idea
  2. Generate outer mold line point cloud
  3. Predict mass and moments of inertia
  4. Predict aerodynamic coefficients
  5. Simulate vehicle dynamics in 6-DOF simulation
  6. Generate stability coefficients
  7. Create prototypes using foam cutter machine
  8. Glide tests off of roof
  9. Select best performing iterations for 3D printed mold
  10. Make carbon composite model
  11. Low altitude UAV drop test (500 ft)
  12. Mid altitude UAV drop test (10,000 ft)
  13. Balloon flights
- (If failed at any point, go back to step 1)

# Vehicle – “AutoCub”



- Risk reduction technology development platform
- Avionics test bed
- Autonomy and flight control system testing

# Vehicle – “Drop Cub”



- Prandtl-m glider "mothership"
- Captive carry and glider launches

# Prandtl-m Prototypes



- Many lessons learned
- Low Reynolds number effects
- Staying subsonic
- Laminar separation
- Inertial Coupling
- Avionics packaging



# Technical Development Challenges



- Rapid prototyping and fabrication
- >50 mile range telemetry
- -65F temperatures
- Battery capacity and avionics survivability
- Getting all avionics within the airfoil thickness
- Development of custom control systems on commercial flight computers



# Carbon Cub Communication System



## Carbon Cub Pixhawk

- Manual flight control
- Switch between flight modes
- Execute doublet maneuvers

## Ground Station

### Telemetry System

- Monitor vehicle status



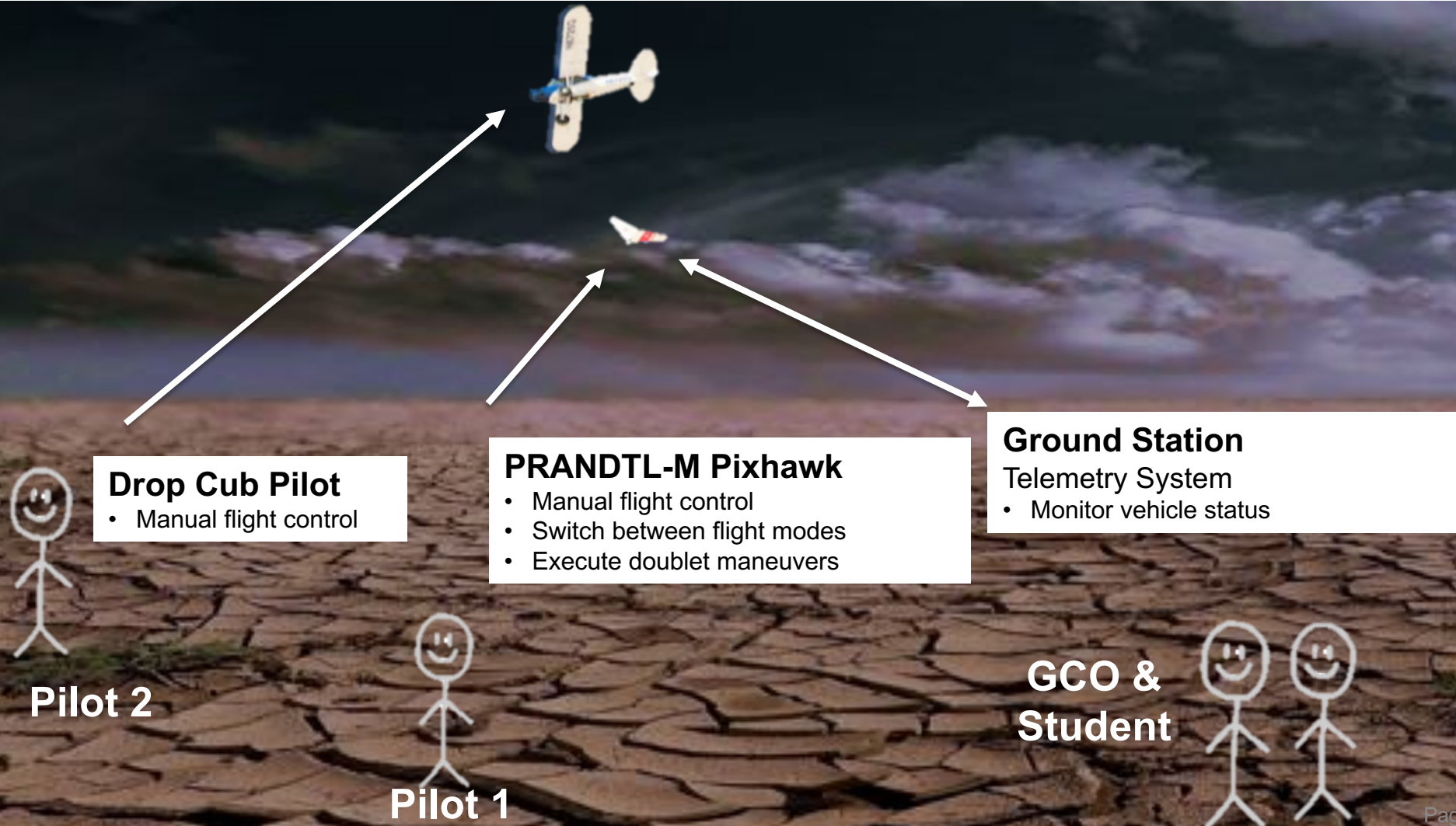
Pilot



GCO &  
Student



# PRANDTL-M Communication System

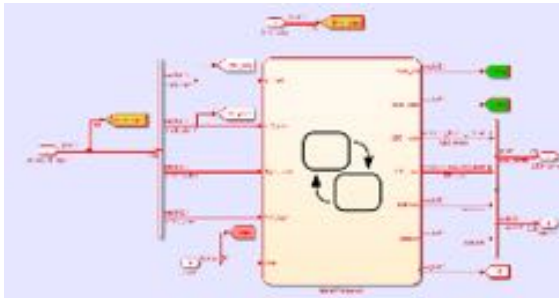




# Control System Toolchain



Block Diagram

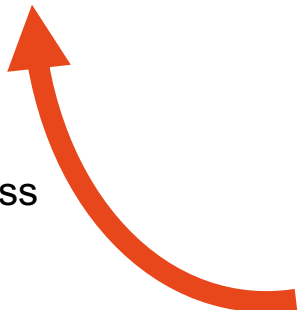


Autocode  
model to C code



```
par1 begin( loop par1);  
/* only update parameters if they changed */  
if (fds[0].revents & POLLIN) {  
    /* read from sensor to clear updated flag */  
    struct parameter_update_s update;  
    sock_recv(sock_in(parameters_update), _sizeof_  
  
    /* update parameters from storage */  
    parameters_update();  
}  
  
/* only run controller if attitude changed */  
if (fds[1].revents & POLLIN) {  
    static double last_roll = 0;  
    float delta = (int) absolute sine() - last =  
    last roll - int absolute sine();  
}
```

Iterate design process

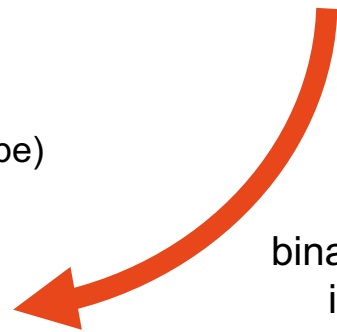


Flight Computer v2 (Cube)



Flight Computer v1

Upload  
binary firmware  
into flight  
computer



# Prandtl-m Team



# NASA Mission Directorates



**Aeronautics Research (ARMD)**



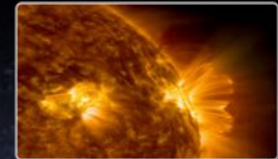
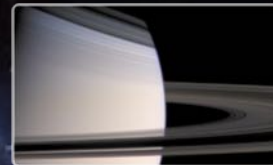
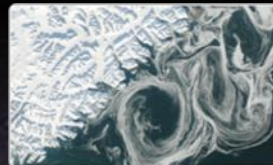
**Human Exploration and Operations (HEOMD)**



**Space Technology (STMD)**



**Science (SMD)**









**Mission Support (MSD)**



# NASA Aeronautics Research Six Strategic Thrusts



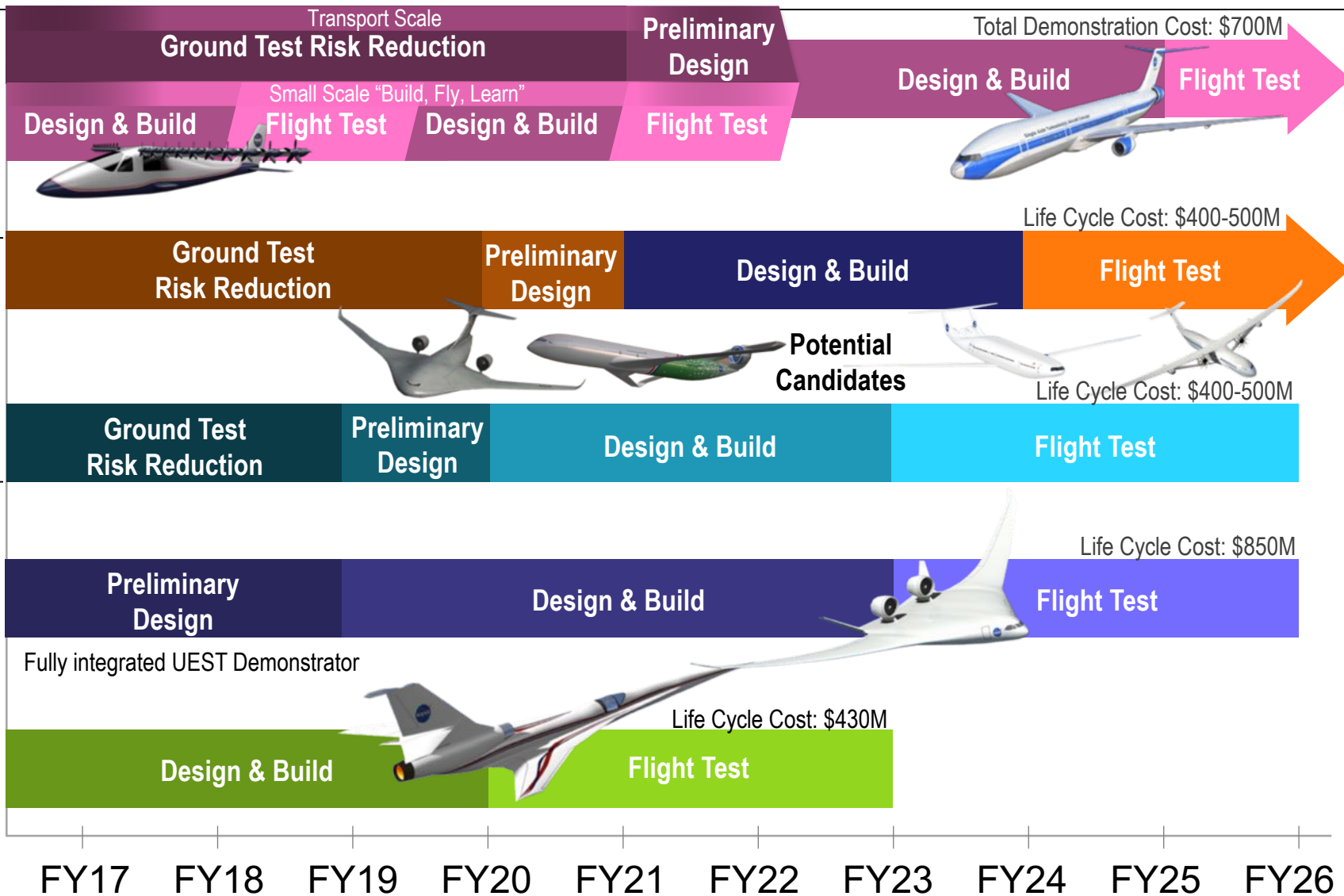
1.  **Safe, Efficient Growth in Global Operations**
  - Enable full NextGen and develop technologies to substantially reduce aircraft safety risks
2.  **Innovation in Commercial Supersonic Aircraft**
  - Achieve a low-boom standard
3.  **Ultra-Efficient Commercial Vehicles**
  - Pioneer technologies for big leaps in efficiency and environmental performance
4.  **Transition to Low-Carbon Propulsion**
  - Characterize drop-in alternative fuels and pioneer low-carbon propulsion technology
5.  **Real-Time System-Wide Safety Assurance**
  - Develop an integrated prototype of a real-time safety monitoring and assurance system
6.  **Assured Autonomy for Aviation Transformation**
  - Develop high impact aviation autonomy applications

# New Aviation Horizons: Flight Demo Plan



Hybrid Electric Propulsion Demonstrators

“Purpose-Built”  
UEST  
Demonstrators



EMBARGOED UNTIL PRESIDENT'S FY17  
BUDGET PROPOSAL RELEASE ON FEB 9



**Flight Loads Lab**



**Advanced Simulation**



**Airborne Science**



**SOFIA**



**Space Technology**



**Space Technology**



**Small Aircraft Research Facility**



**Small Aircraft Research Facility**



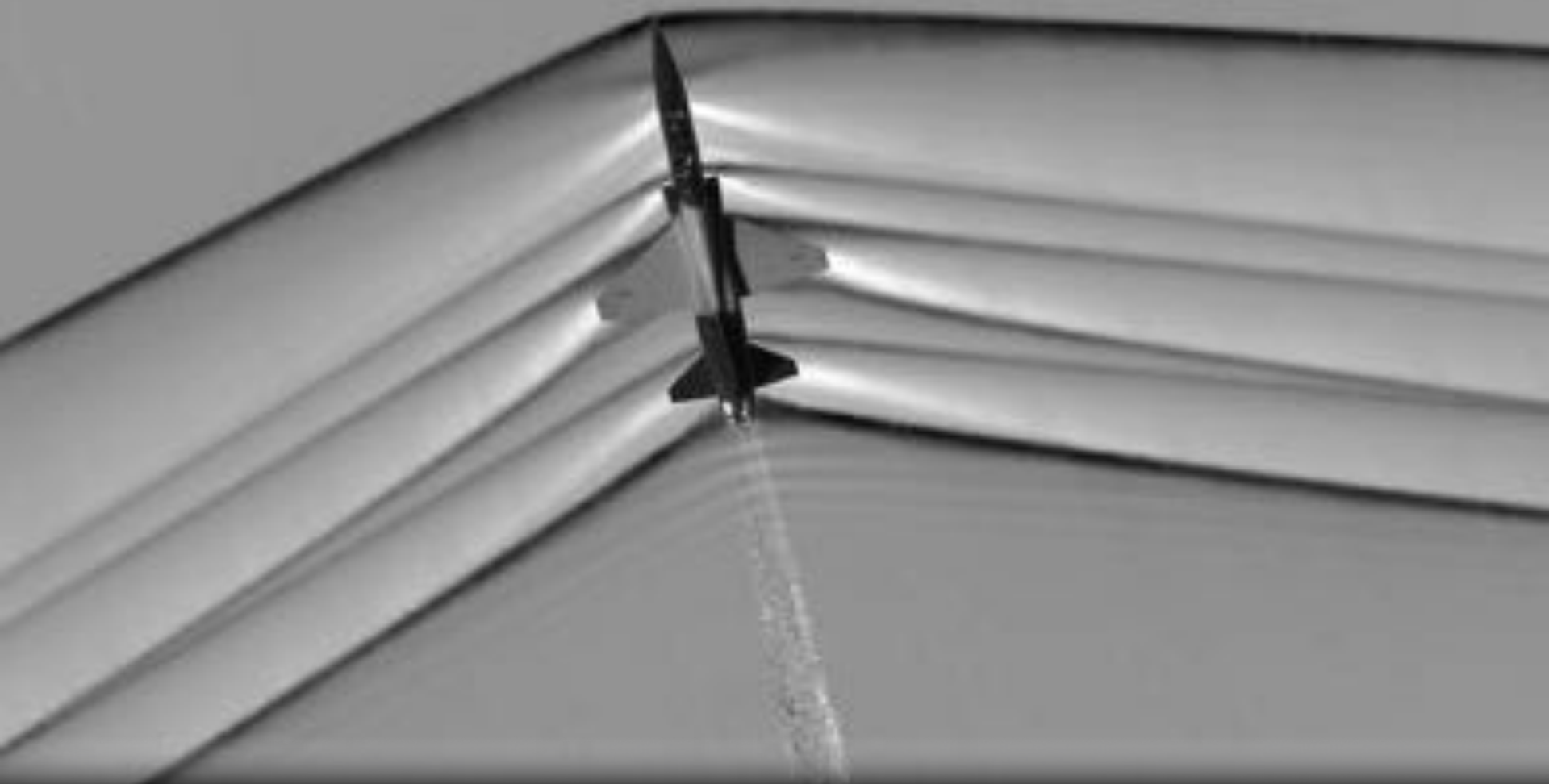
**PRANDTL**



**High Speed Flight Research**



**High Speed Flight Research**



**Low Boom Supersonic Flight**



**Low Boom Supersonic Flight**



**Electric/Hybrid Electric Aircraft**



**Electric/Hybrid Electric Aircraft**



**Electric/Hybrid Electric Aircraft**



**Aeronautics Research**



**Aeronautics Research**



**Aeronautics Research**



**Aeronautics Research**



**Aeronautics Research**



**Aeronautics Research**

# NIFS-NASA Internships Fellowships and Scholarships

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- Traditional student internships and faculty fellowships
- Spring (16 weeks), Summer (10 weeks), and Fall (16 weeks)
  - Full time and on-site (40 hours per week)
  - Require US Citizenship (Ames and JPL have international student programs)
  - <https://intern.nasa.gov/>
  - HS Seniors through post-docs

# Unsolicited Advice



- There is no “NASA Smart”
- Please do not wait to start applying to what you want
- Pursue excellence, even if you are not where you want to be right now
- There is never a “good time” to change schools, take that internship, make a life change, so do not wait for it
- If you are not failing/struggling at something, you probably are not challenging yourself enough (don't be afraid to fail)



Questions?

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