

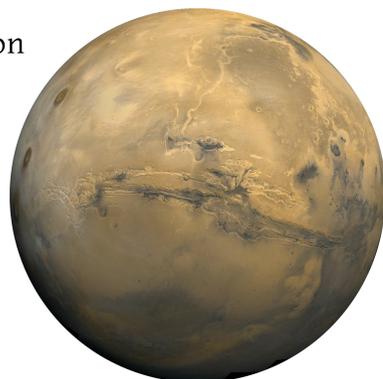
A Fault-Tolerant UAV Autopilot System for Mars Exploration

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Motivation

Problem: Existing Mars exploration technologies are limited

- Landers only interact with immediate surroundings
- Rovers too slow to cover much ground
- Orbiters too far away to get high resolution data



Solution: an Unmanned Aerial Vehicle (UAV)

- Explore large regions quickly
- Can be directed to focus on a particular area of interest
- Atmospheric sampling capability

The Project

Objective: Explore design considerations required for a Mars exploration UAV

Plan: Build and test an avionics package with redundant components to increase overall system reliability

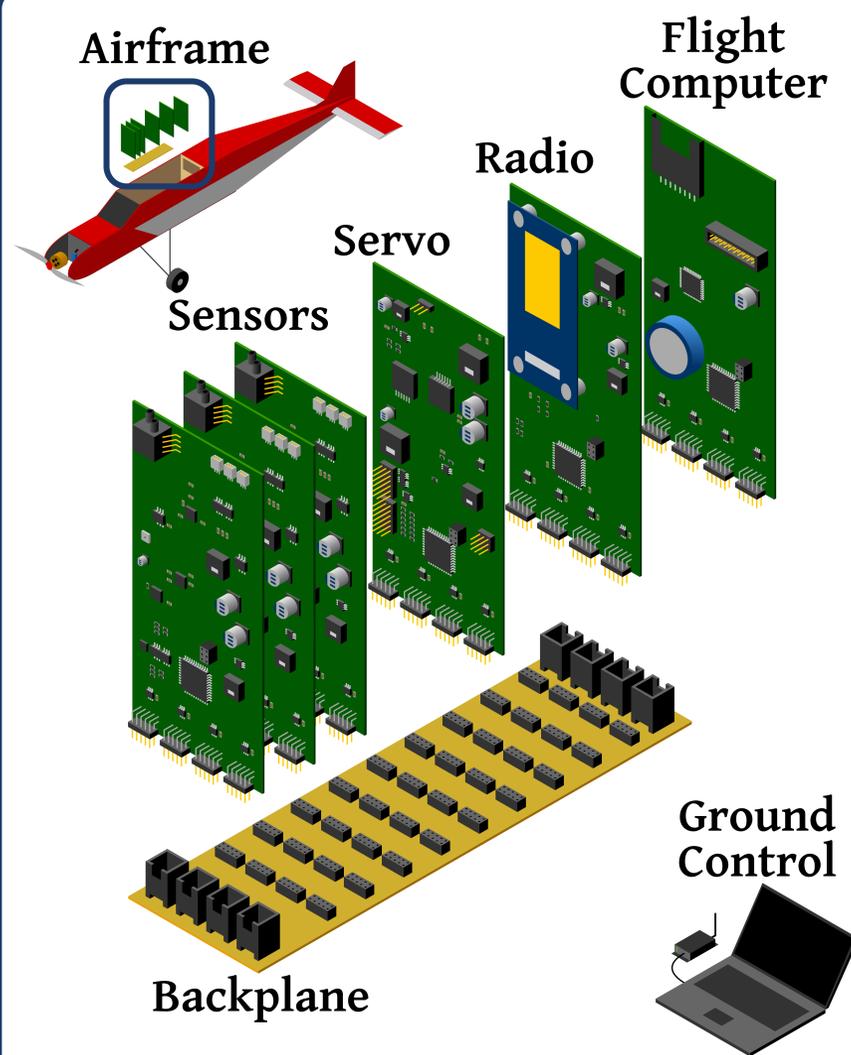
Design Specifications

- **Redundant Sensors:** survivability in harsh environment
- **Flexibility for Future Expansion:**
 - Hardware design allowing fully redundant components
 - Extra modules can include scientific payloads
 - Consideration for moving to a launchable design

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Modular Extensible Flight Control System Full Custom Hardware and Software Fault-Tolerant Sensors and Power

Flight Computer

- Custom real-time operating system
- ARM microcontroller runs autopilot control loop
- System bus master

Sensors

- Multiple boards provide fault-tolerance
- Each board includes:
 - Three-axes each of: gyroscope, accelerometer, magnetometer
 - Barometric altimeter
 - Pitot-tube airspeed
 - External Garmin GPS

Airframe

- Electronics portable between aircraft models
- Tested with off-the-shelf electric Senior Telemaster
- Modified to add pitot tubes, radio antenna, and GPS receivers

Radio

- Receives ground commands
- Sends real-time telemetry
- Bus voltage monitoring
- Line-of-sight 40 mile range

Ground Control

- Satellite map viewer for real-time tracking
- X-Plane live 3D visualization
- Real-time telemetry logging
- Tools for telemetry analysis
- Emulation for debugging
- Flight plan creation

Backplane

- Multiple data and power lines
- RS-485 protocol on data wires

Servo

- Manipulates control surfaces
- Manual R/C backup receiver
- Distributes battery power
- Battery power monitoring

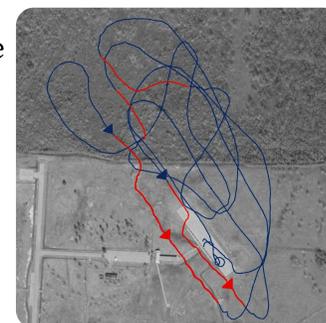
Autopilot Flight Test

Goal: Demonstrate ability to maintain aircraft heading and attitude

- Plane initially flown manually, switched to autopilot mid-flight
- Set to maintain last heading

Results: Aircraft maintains desired heading

- Limited yaw oscillations
- Acceptable pitch stability



GPS path overlay on satellite map
Red indicates autopilot active

Proven Real Flight Results

We successfully created and tested an avionics package for a fixed-wing UAV that employs sensor redundancy for fault-tolerance:

- Designed and fabricated a complete set of avionics hardware
- Wrote and tested firmware for all on-board electronics
- Developed ground software for real-time UAV monitoring, telemetry analysis, and system simulation/testing
- Demonstrated basic autopilot functionality with redundant sensors in a real flight environment

• PC mapping software
• Autopilot design

• System architecture
• Initial hardware design

• Initial hardware built
• Servo board flight test

• Inter-board communication

• Sensors integration
• Custom operating system

• New hardware revision
• Sensors flight test

• Autopilot integration
• Glide flight testing

June

2010

August

October

December

February

April

2004

2011