NIWeek

cRIO Takes Flight
Creating a Helicopter Autopilot

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VIEWPOINT SYSTEMS

www.viewpointusa.com

Presented by: Timothy Dykes

- Viewpoint Systems, a National Instruments Platinum Alliance Partner
- Systems Architect
- Certified LabVIEW Architect
- Certified NI Professional Instructor
- Background in Aerospace, including hydraulics, pneumatics, electronics, and high power systems, PMS (BLDC) Motors
- Started programming LabVIEW in 1997

NATIONAL INSTRUMENTS LabVIEW CERTIFIED ARCHITECT

NATIONAL INSTRUMENTS Certified Professional Instructor

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Safety First!

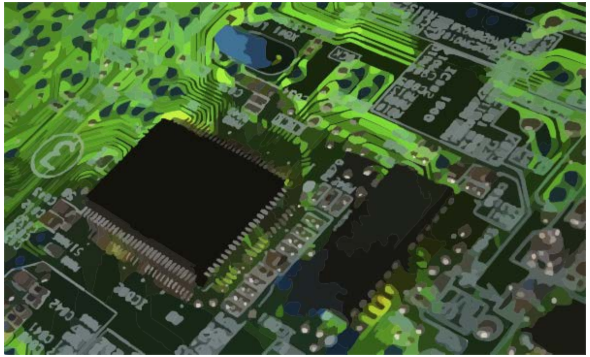
- We flew a full size helicopter, our lives depended on it
- Loss of life or aircraft is NOT an option
- First Layer: Software designed to disengage on faults
- Second Layer: Electrically actuated method to disengage
- Third Layer: Mechanical disconnect from controls
- cRIO is NOT flight certified hardware, aircraft flown experimental

FAA Requirements

- Flying modified aircraft will require FAA approval
- The type and amount of modification may result in restrictions
- Aircraft may receive an “experimental” classification

The Challenge

- Test new system concepts, in flight, cost-effectively
- Rapidly and safely develop and test new algorithms
- Avoid the need for custom hardware not related to the task



Custom Circuits

Off The Shelf

Enter cRIO, Off The Shelf Flight Controller

- cRIO can perform every aspect of a flight controller
- Motor drive modules can operate small actuators
- Analog modules for input and output
- Digital modules for discrete I/O
- RS232, 422, 485, and Ethernet for common protocols
- ARINC-429 by NI Partner SEA for aircraft communications

How Does a Helicopter Fly?

- 3 main controls “Cyclic” “Collective” and “Pedal”
- Cyclic changes angle of main rotor thrust
- Collective changes amount of thrust
- Pedal controls thrust of tail rotor

Using the Helicopter Controls - Cyclic

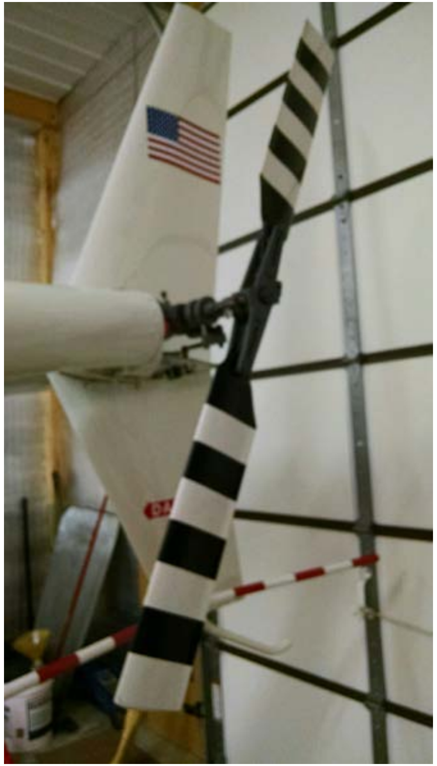
- Cyclic has two axis of movement
- Moving the cyclic controls pitch or roll the aircraft
- Pitch affects fore and aft motion
- Roll affects left and right motion

Using the Helicopter Controls - Collective

- Collective changes pitch of main rotor blades
- Controls amount of lift generated or power
- Collective changes require pedal reactions

Using the Helicopter Controls - Pedal

- Controls thrust generated by tail rotor
- Must be adjusted to cancel main rotor torque
- Used to make coordinated turns and yaw aircraft



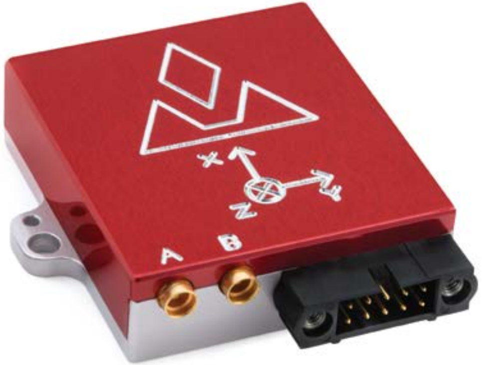
Interfacing To the Real World - Outputs

- Electric actuators to control flight surfaces
- cRIO 9502, 9503, 9505 motor drive modules for small actuators
- cRIO 9375 for outputs to drive enables and indicators

Interfacing To the Real World – Inputs

- Attitude heading reference system (AHRS)
- Gives pitch, roll, yaw, angles, rate of change, acceleration
- GPS based latitude, longitude, altitude
- Air data, air speed and pressure base altitude

Pitot Static Tube



VectorNav Technologies

S.E.A. Datentechnik GmbH

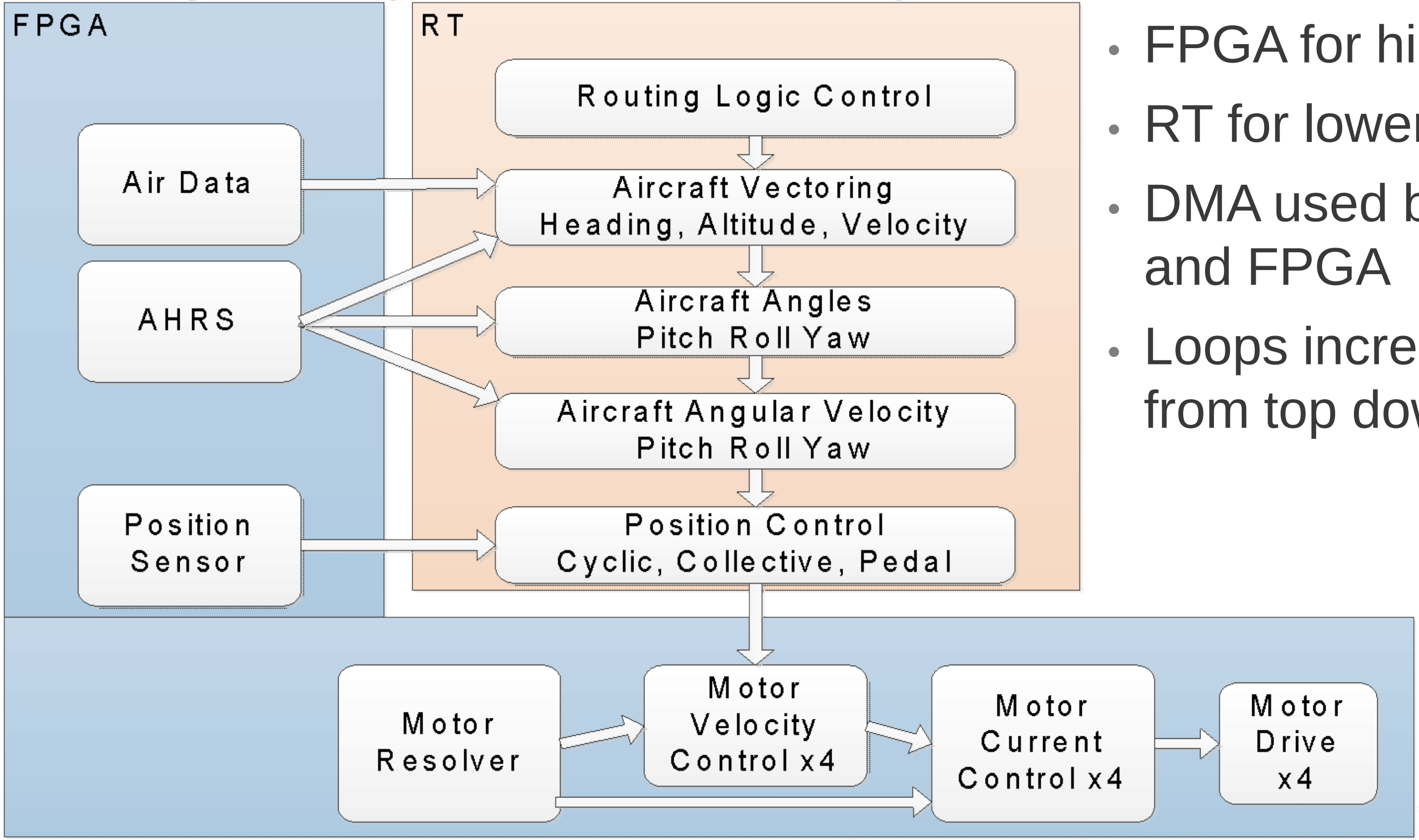
Attitude Heading Reference System

- Uses accelerometers, magnetometer, gyroscope, and GPS
- Kalman filter to combine sensor data
- Rotational pitch-roll-yaw: angles and rates
- Linear X-Y-Z accelerations
- GPS data, latitude, longitude, altitude, velocity

Anatomy of a Flight Controller

- Consists of many nested loops working together
- cRIO can do them all, 9082 has room to spare
- FPGA used for motor control, I/O, safety monitor
- RT used for position and flight control

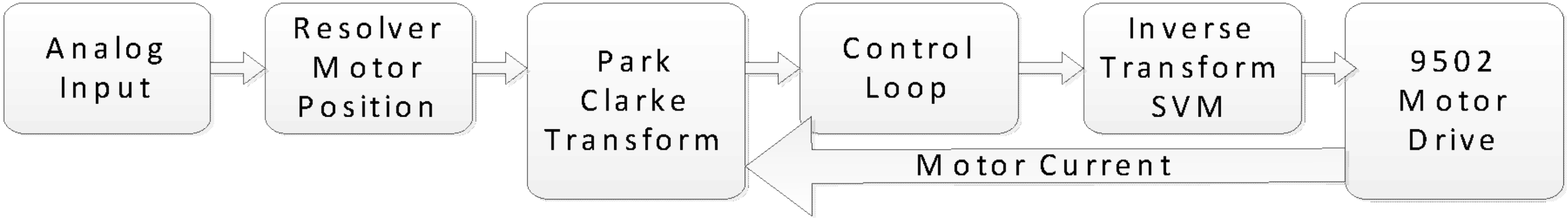
Example Flight Controller Algorithm



- FPGA for high rates
- RT for lower rates
- DMA used between RT and FPGA
- Loops increase in rate from top down

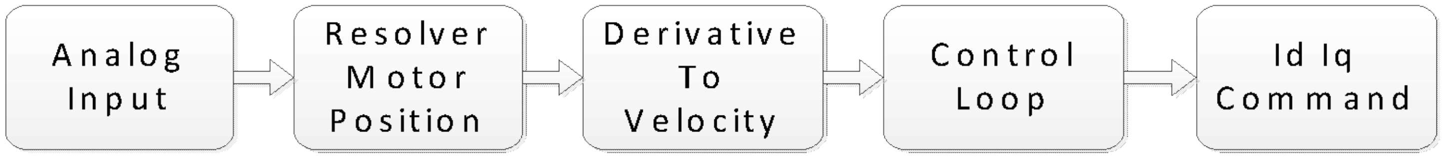
Motor Control – Current

- 9502 Servo Drive module
- Module has no Control, just a driver
- A custom aerospace controller was leveraged from previous work
- This control algorithm handles higher dynamics found in aircraft
- 9502 measures current feedback from motor
- Control algorithm calculates PWM output for 9502



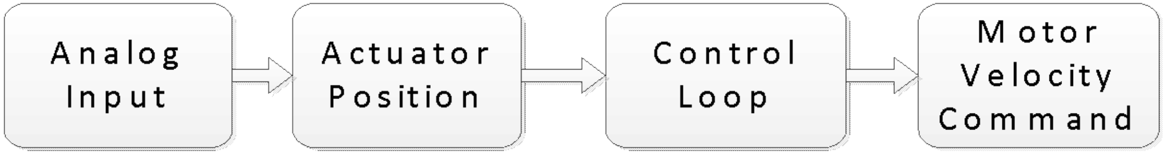
Motor Control - Velocity

- Additional analog input used to measure motor position and speed
- Velocity loop custom aerospace algorithm
- Uses velocity feedback to calculate current command
- Currents are in the D-Q frame



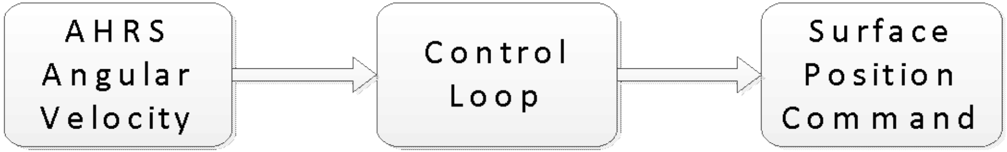
Actuator Position Control

- Reads position sensor on actuator
- Various sensor types can be used: LVDT, resolver, potentiometer
- Calculates a velocity command to meet position
- Limits applied to surface displacements



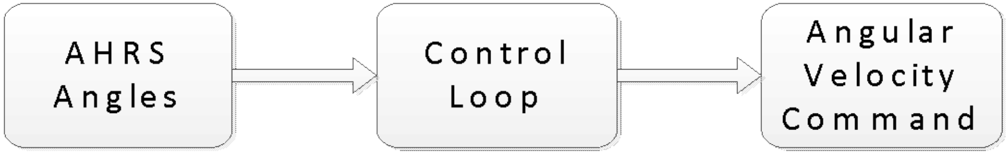
Aircraft Angular Velocity

- Reads angular velocity from AHRS
- Pitch roll yaw velocity has highest bandwidth from AHRS
- Higher bandwidth assists with external disturbances
- Handles changes in aircraft dynamics
- Calculates position commands for surfaces
- Limits applied to maximum angular velocity



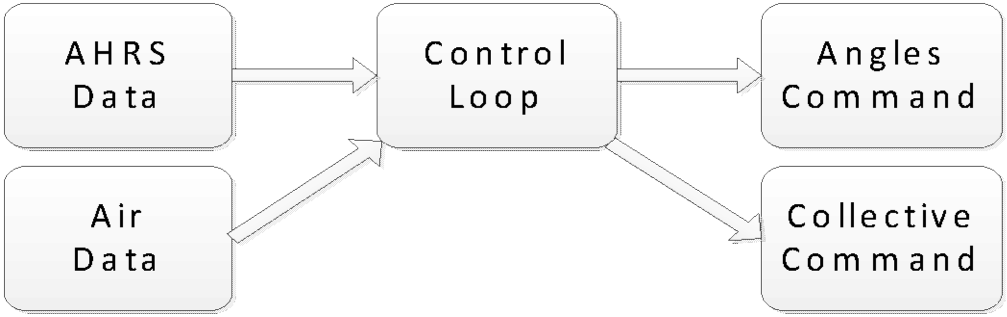
Aircraft Pitch Roll Yaw Angles

- Reads AHRS pitch roll yaw angles
- Minimum level to keep aircraft stable
- Changing pitch effects velocity and altitude
- Changing roll effects heading
- Slower rate due to AHRS gyroscope and Kalman filter
- Commands an angular velocity to maintain angles
- Limits applied to maximum angles allowed



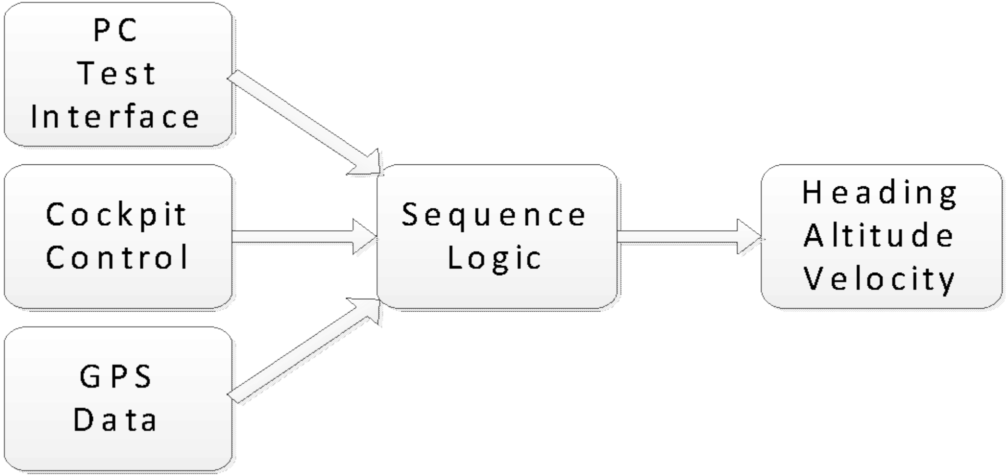
Heading, Altitude, Velocity

- Finally can control where we want to go!
- Reads heading from AHRS
- Reads altitude and velocity from AHRS and air data
- Calculates pitch, roll, yaw angles, collective power setting
- Maintains commanded heading, altitude, velocity
- Rate of change limits for standard flight operations



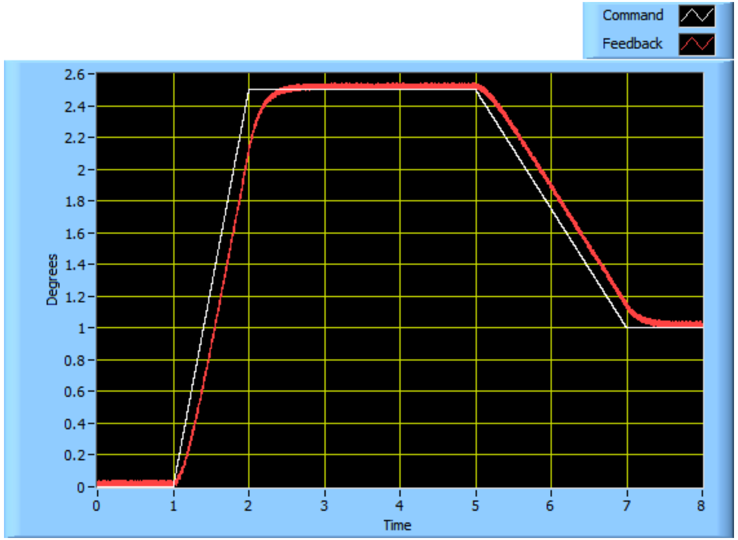
Routing Controller

- Inputs a course or series of GPS waypoints
- Logic to transition when waypoint is reached



Non-Flight Controller Functions

- High speed data recording at motor control rates
- Ethernet data stream for real time monitoring
- Ability to update control coefficients while in flight



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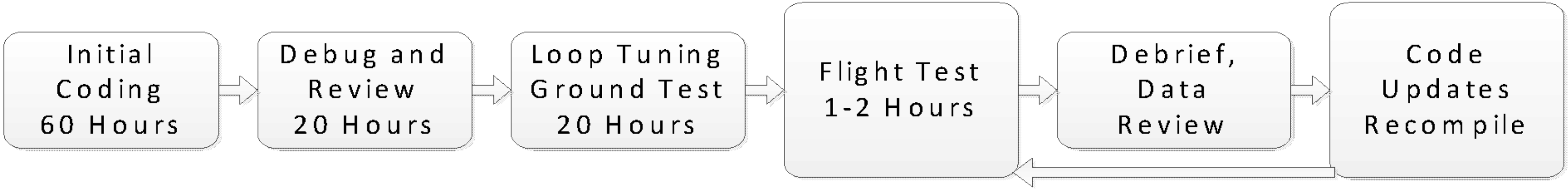
Schedule

- The cRIO controller was coded, tested, and flew in 100 hours
- Hardware connections took another 100 hours in parallel
- From start to completion of flight testing was 3 calendar months
- 90% code reuse from existing projects



100 Hours Total Design Effort

100 Hours Total Flight Testing
4 Hour Update Interval
2 Flights Per Day

Results

- cRIO performed flawlessly
- All initial goals were met after 2 days of flight testing
- An additional 2 weeks of expanded testing
- At completion the system could fly a preprogramed route
- Hold a hover at a GPS coordinate at ground level and altitude

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Questions??

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