Introduction to Berkeley UAV Project BEAR

David H. Shim, Tak-Kuen Koo, Frank Hoffmann,
Omid Shakernia, Jin Kim, Cedric Ma,
Bruno Sinopoli, Tullio Celano,
William Morrison, Shahid Rashid, Santosh Phillp
Shankar Sastry
University of California, Berkeley

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Presentation Outline

1. Introduction of Berkeley UAV Fleet
2. Overview of Berkeley UAV Navigation System

Berkeley BEAR UAV Research

The Goal

Develop theoretical methodologies and experimental platform for

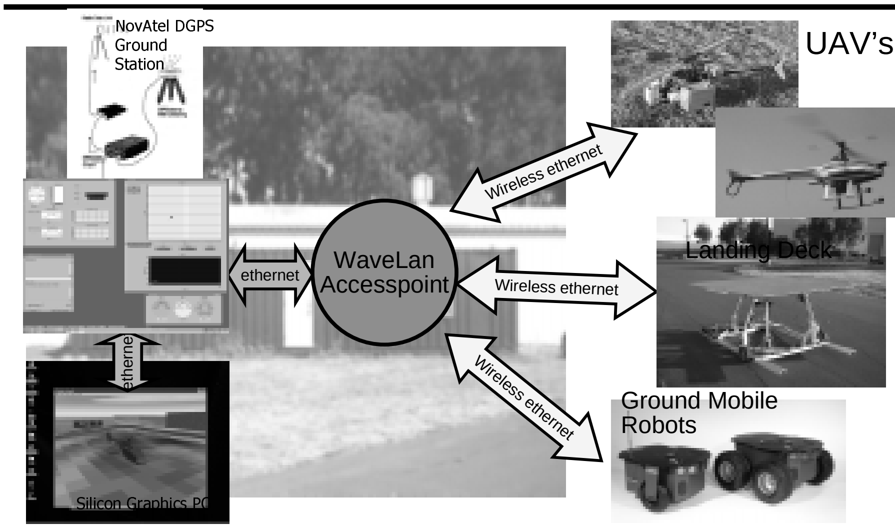
- vision-based landing
- multi-agent coordination
- landing on a pitching ship deck
- advanced guidance and control law

Berkeley BEAR UAV Research

3. Project History

August 1996: First helicopter assembled. Payload test (Ursa Minor 1)
October 1997: Ursa Minor 1 assembled based on Crossbow Accelerometer
April 1998: Second helicopter assembled: Ursa Minor 2
July 1998: Ursa Minor reconfigured with MotionPak based navigation
August 1998: Ursa Magnus joined
August 1998: Participated in UAVS competition at HAMMER, WA
September 1998: First instrumented flight using Ursa Minor 2
October 1998: Ursa Minor 3 joined
December 1999: research paper presented in IEEE CDC at Tampa, FL
Dec. 1998-Mar. 1999: mu-synthesis based attitude controller tested
March 1999: Boeing DQI-NP based navigation system implemented
June 1999: Yamaha R-50 purchased. Named to "Ursa Magnus"
August 1999: First instrumented flight using Ursa Magnus 2

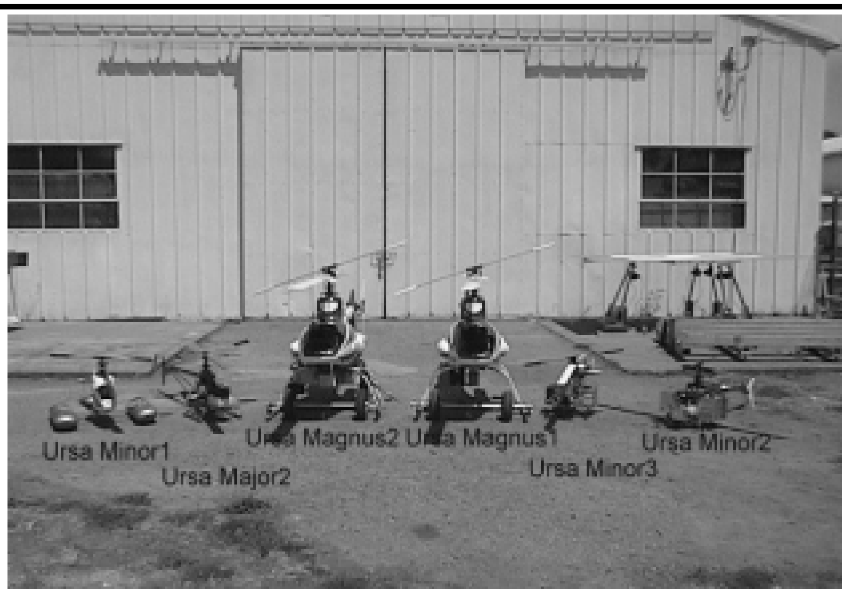
Berkeley UAV Research Platform



Ground Monitoring System

WaveLAN: T. John Koo
Pioneer mobile rotot: Omid Shakernia, Frank Hoffman
Pitching deck landing pad: Tulio

Berkeley BEAR Team Fleet Line-up



Berkeley BEAR Team Fleet Line-up

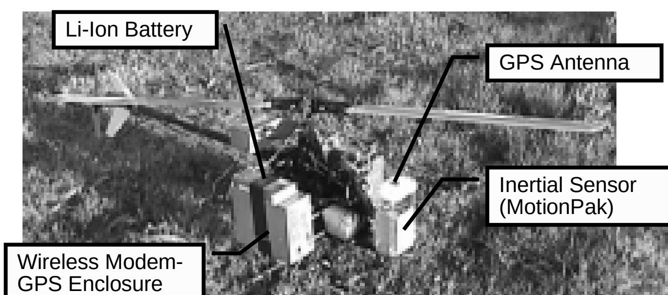
1. Ursa-Minor Series (1,2,3)
   Based on Kyosho Concept 60
   Modified OS FX-91(14cc) 2cycle engine (Ursa Minor 2,3)
   Payload: 5kg

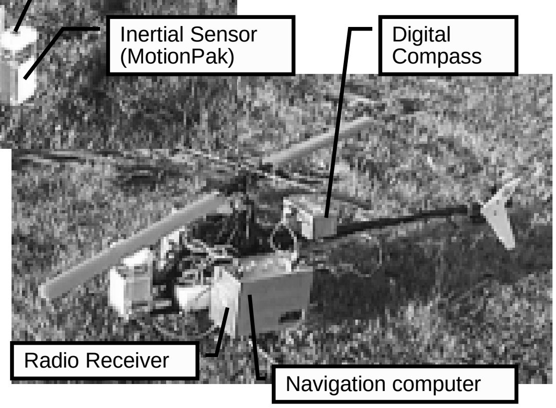
Ursa Minor 1: retired to Trainer
Ursa Minor 2: Engineering Plastic Composite body
MotionPak based navigation system
Ampro Pentium 233MMX Littleboard

Ursa Minor 3: Graphite body (stiffness)
Boeing DQI-NP based navigation
Cyrix MediaGX 233MHz PC104 board

DQI-NP: Digital Quartz Inertial Measurement Unit with Navigation Processor

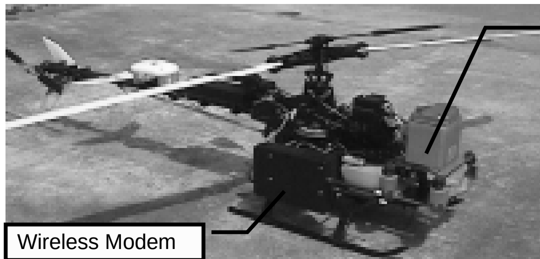
Ursa Minor 2

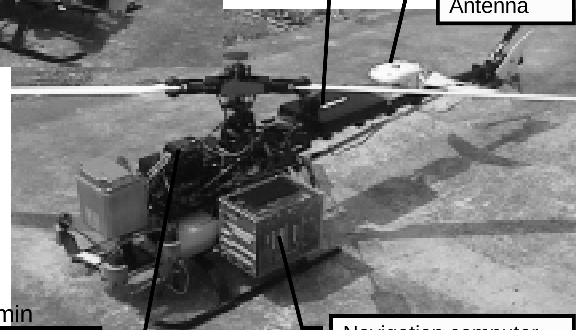




Length: 1.4m
Width: 0.39m
Height: 0.47m
Weight: 9.3 kg
Engine Output: 2.8 bhp
Rotor Diameter: 1.5m
Flight time: 15 min
System operation time: 30 min

Ursa Minor3





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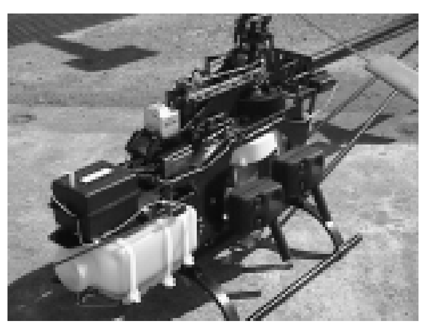
Width: 0.39m
Height: 0.47m
Weight: 9.4 kg
Engine Output: 2.8 bhp
Rotor Diameter: 1.5m
Flight time: 15 min
System operation time: 30 min

Berkeley BEAR Fleet Line-up

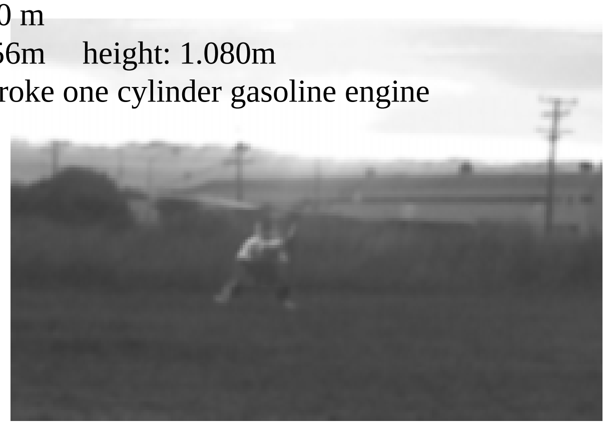
2. Ursa-Major Series
   Based on Bergen Industrial Twin helicopter
   Payload: >10kg



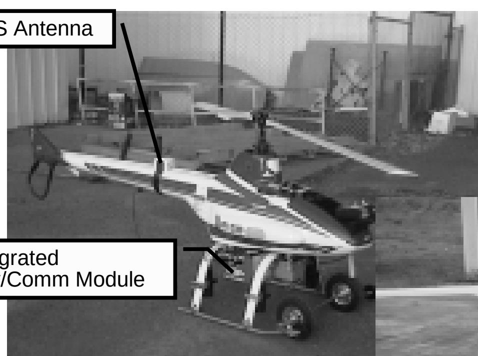
Berkeley BEAR Fleet Line-up

3. Ursa-Magnus Series
   Based on Yamaha R-50 industrial helicopter

   Rotor diameter: 3.070 m
   Fuselage length: 2.656m height: 1.080m
   Water-cooled, two stroke one cylinder gasoline engine
   Dry weight: 44kg
   Payload: >20 kg

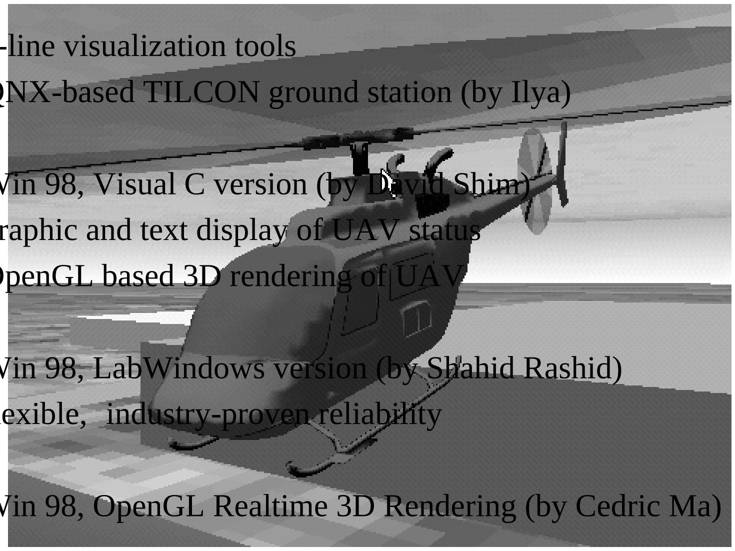


Onboard Hardware: Ursa Magnus2



Length: 3.6m
Height: 1.08m
Dry Weight: 44 kg Payload: 20kg
Engine Output: 20 hp
Rotor Diameter: 3.070m
Flight time: 30 min
System operation time: 60 min

Existing Tools- Visualization



- On-line visualization tools

1. QNX-based TILCON ground station (by Ilya)

2. Win 98, Visual C version (by David Shim)
   graphic and text display of UAV status
   OpenGL based 3D rendering of UAV

3. Win 98, LabWindows version (by Shahid Rashid)
   flexible, industry-proven reliability

3. Win 98, OpenGL Realtime 3D Rendering (by Cedric Ma)

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Test Flight Video

Ursa Magnus 2: “frequency sweeping” flight for system id

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Test Flight Video

Ursa Minor-1: landing on the ship-motion deck

Navigation Software

- **Real-Time OS: QNX**

- **Advantages**

- Systematic way to write Real-time programs
- UNIX-like system architecture
- Very compact kernel
- Advanced Inter-Process Communication(IPC) support

- **Drawbacks**

- Latency issues
- Limited number of supporting hardware
- Limited number of available application software

Navigation Software- Features of QNX

- **Multiprocessing (priority)**

- **IPC**
  Messages, proxies, shared memories

- **Real-time feature**
  supports PC hardware interrupts via *Proxy*

- **Scheduling**: process priorities, states and algorithms
  Priorities: 0(lowest)-31(highest)
  States: *READY*, *BLOCKED*(*send-*, *receive-*, *reply-blocked*)
  Algorithm:*FIFO*, *Round-robin*, *Adaptive*

Navigation Software- Network support

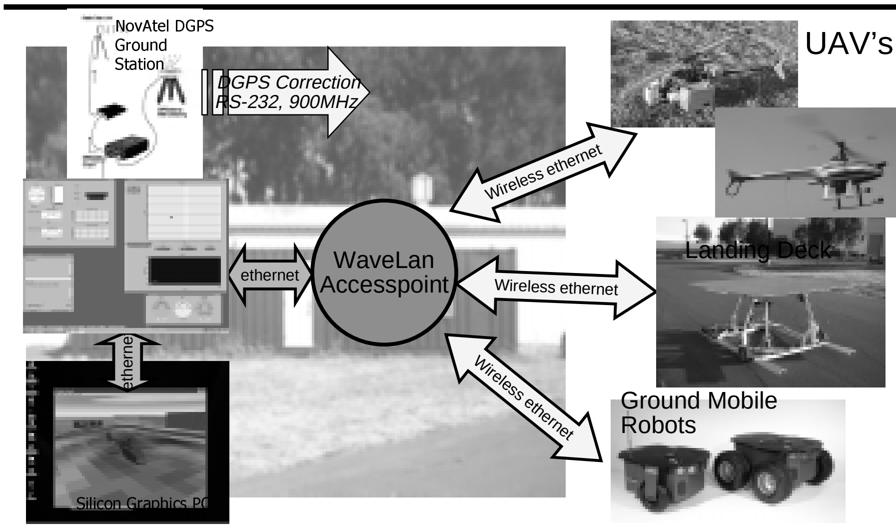
Network support of QNX

- QNX-only network: seamless virtual machine distributed over network (supports TCP/IP, peer-to-peer RS-232)
  supports spawning processes and IPC over network

- Heterogeneous network: QNX and non-QNX computers (TCP/IP)
  Flight info download and command upload using TCP/IP

- CORBA on QNX: Orbix by IONA (www.iona.com)

Berkeley UAV Network Configuration



Ground Monitoring System

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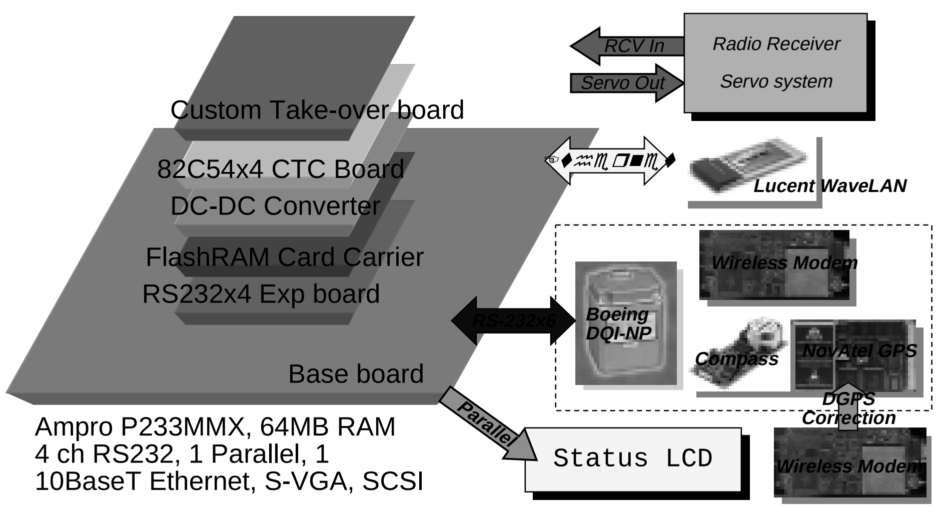
Navigation Hardware

1. Navigation Computer Configuration



Ampro P233MMX, 64MB RAM
4 ch RS232, 1 Parallel, 1
10BaseT Ethernet, S-VGA, SCSI

Navigation Hardware

- Navigation computer

- Navigation Sensors
  Boeing DQI-NP, NovAtel GPS(Millen RT-2), Digital Compass,
  Ultrasonic height meter (x4)

- Miscellaneous sensors: contact switch(x4), engine encoder

- Communications
  900MHz Wireless modem(x2), Lucent WaveLan(2.4GHz)

- Vision System
  Stereo camera on Pan-Tilt-Verge Platform, Video transmitter
  On-board vision processing computer (Ampro P233MMX)

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Navigation Software: DQI-NP-Based

Tasks of Onboard Navigation Computer Software

1. Initialize navigation sensors(GPS, IMU)
2. Acquire sensor information from GPS, IMU, Ultrasonic height meters
3. Update the Boeing DQI-NP using GPS measurements
4. Calculate the stabilizing and tracking control output
5. Download system status and navigation information
6. Process uploaded command from ground station

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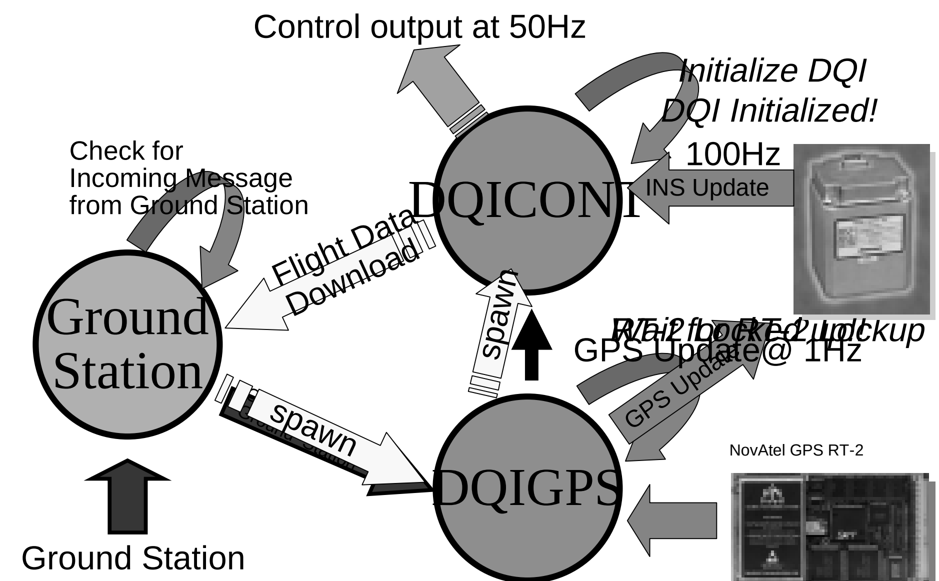
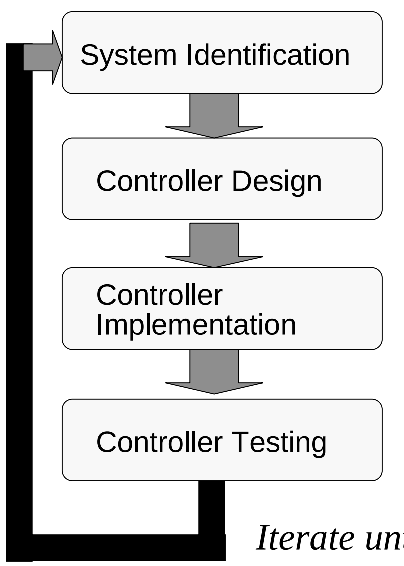
Navigation Software: DQI-NP-Based



System Integration Procedure



- Parameter acquisition (step through)
- System estimation/validation with input-output samples

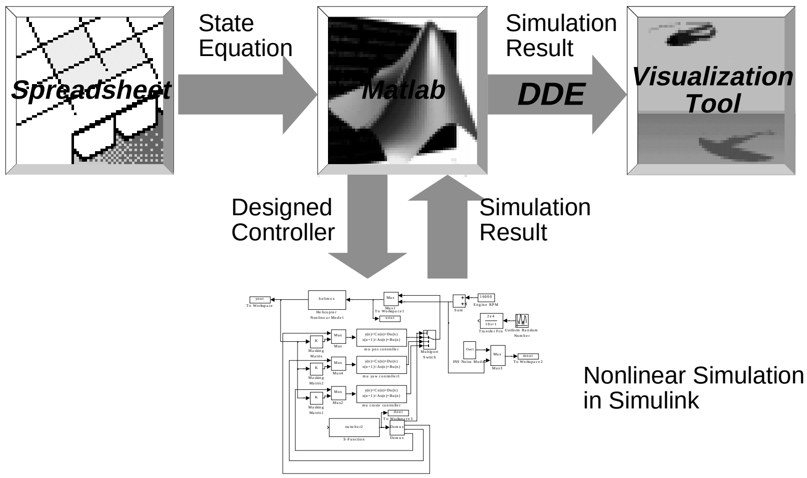
- Different design methods and benchmarks
- ***Robustness issue***

- Code generation (Manual or Computer-aided)

- To evaluate the controller performance
- Serious difficulties and risks involved

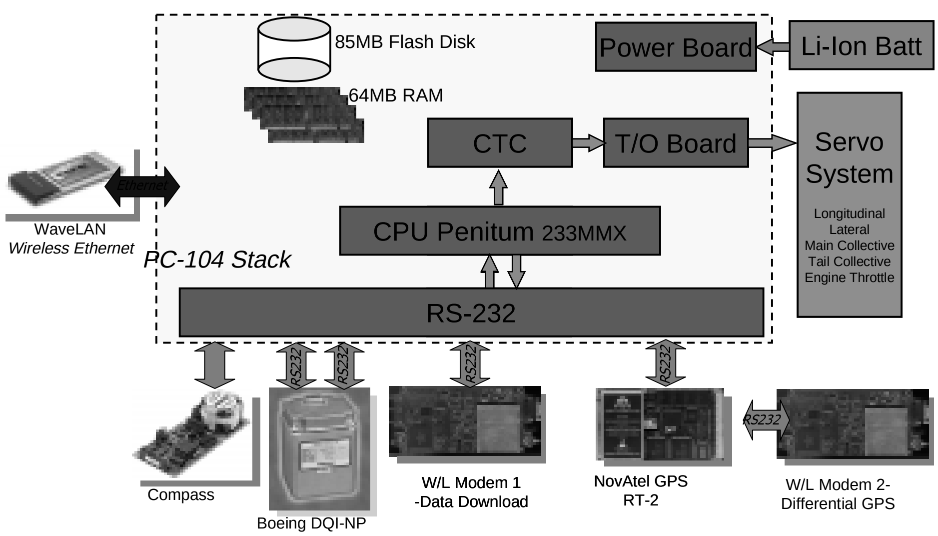
Iterate until satisfied

Integrated Development Environment



Navigation Hardware

1. Ursa Magnus 2: Boeing DQI-NP based system



UAV Design Philosophy

- **Functionality**

  install the necessary sensor systems and processors to perform the given task: autonomous take-off/landing, hover, way-point navigation
- **Light & Compact Design**

  Weight reduction for better flight performance

  Use compact parts and enclosures to minimize the inertia and maximize the rotor efficiency
- **Modularity**
- **Safety and Reliability**
- Minimization of interference among components

Complications in System Integration

- Base system: a model helicopter with unknown parameters
- Integration of diverse mechanical and electronic components, most of which were not intended to be used in harsh environment
- Interference among system components

  interference among W/L modem, GPS, Video Tx, radio controller...
- Exhausting process of Trial and Error
- Special issues in operation:

  - Not-friendly operation environment

    heat, vibration, shock, dirt, oily spray, etc...

  - RELIABLILTY, SAFETY