DU Unmanned Systems Laboratory, *DU²SL*

Enabling Intelligent Unmanned Vehicles Through XMOS Technology *

Gonçalo Martins
Allistair Moses
Matthew J. Rutherford
Kimon P. Valavanis

Department of ECE

* This work appeared in the Journal of Defense Modeling and Simulation

June 2011

UNIVERSITY OF DENVER

Outline

- Motivation
- Proposed Platform
- Unmanned Systems Applications
- Evaluation
- Conclusions

UNIVERSITY OF DENVER

Motivation

- Current technology – platforms:
  - PIC from Microchip
  - ARM architecture (GumStix, BeagleBoard, Linux OS)
  - PC 104
  - x86 architecture (Linux OS)
  - ATMega
  - FPGAs

Motivation

- Current technology – drawbacks:
  - For platforms that use Linux OS
    - Real time and non real time OS
    - Threads synchronization and communication
    - Poor flexibility on I/O interaction
  - Without OS (such as PIC or ATMega)
    - Interrupt routines
    - Limitted amount of operations or functions simultaneously
    - Timers (quantity and resolution)

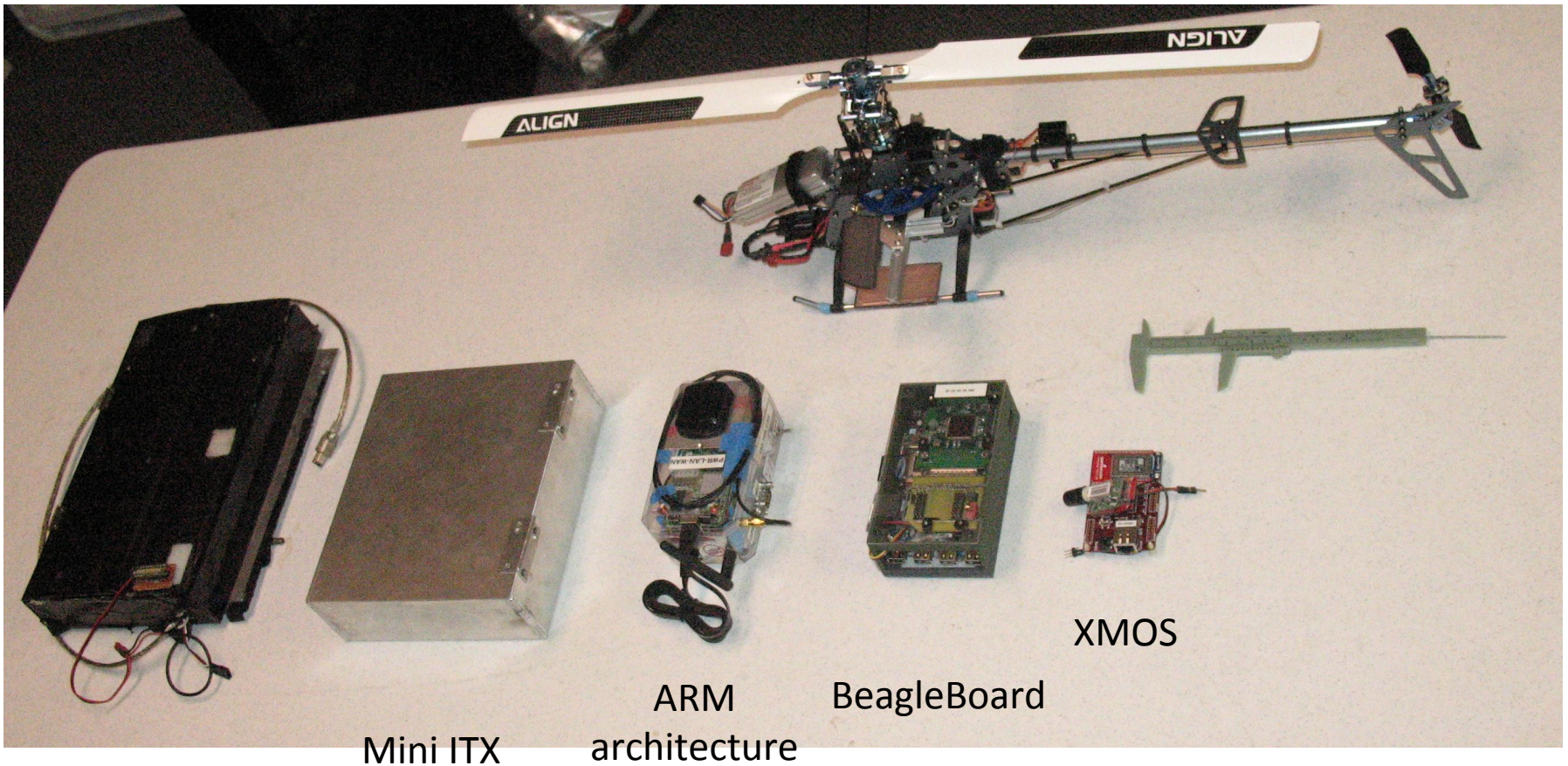
Proposed Platform

- XMOS technology
  - ➢ Fast I/O interaction
    (Uart, SPI, I2C, Ethernet controller, 1 wire protocol)
  - ➢ Real time capability (event driven)
  - ➢ Scalability (over Xlinks)
  - ➢ Programming languages: XC, standard C and C++
    (Eclipse development environment)
  - ➢ Each core can has 8 threads running simultaneously with 64KB of memory
  - ➢ Available development boards with 1, 4 and 16 cores

UNIVERSITY OF DENVER

Proposed Platform

- Different DU^{2}SL controller generations for UAVs:



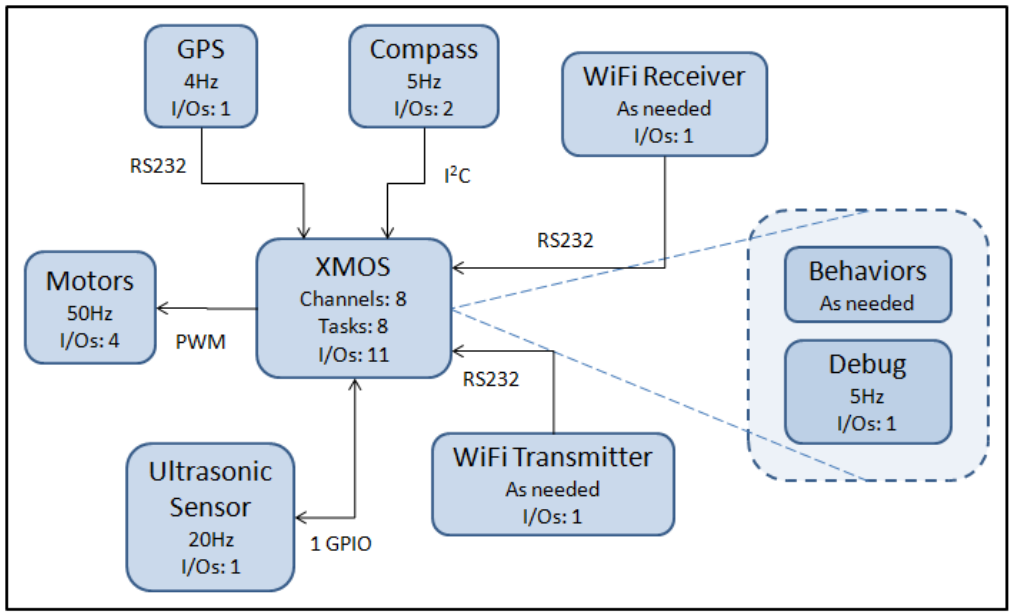
UNIVERSITY OF DENVER

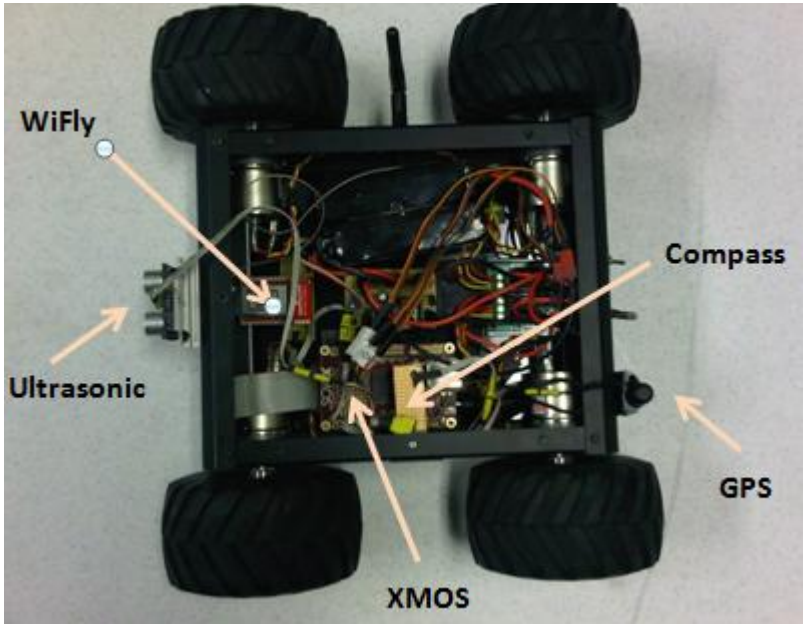
Unmanned Systems Applications

- Development board used: XC-2
  - 4 Core (32 concurrent threads)
  - 256KBytes single-cycle SRAM
  - 400 MHz
  - 10ns timing resolution
  - More than 84 I/O pins
  - Scalable and deterministic on and off-chip communication

Unmanned Systems Applications

- Unmanned Ground Vehicle (UGV):
  - ➢ Current version uses 8 threads for autonomous operation
  - ➢ 24 threads remain for application tasks

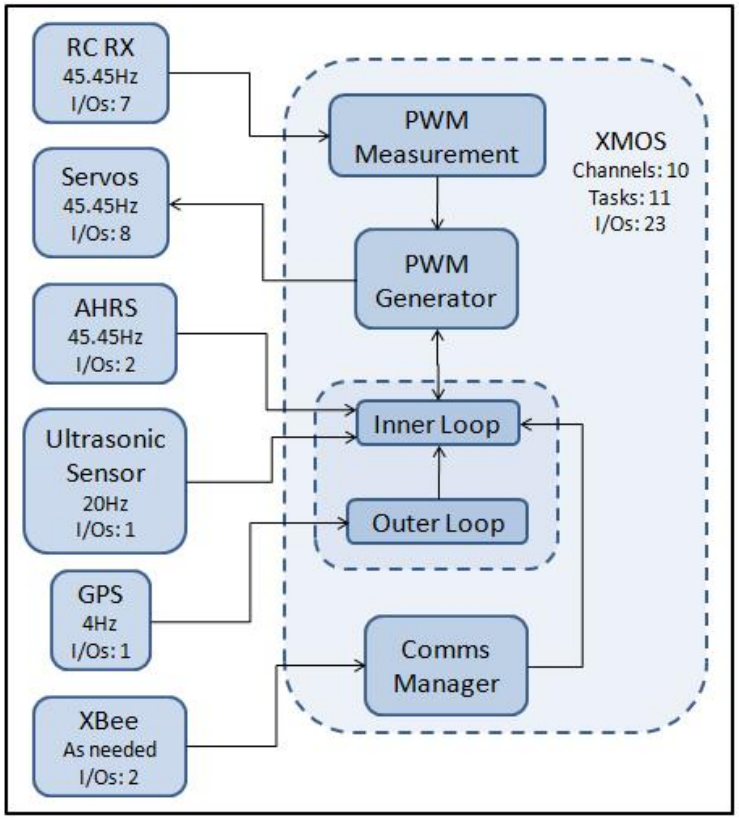


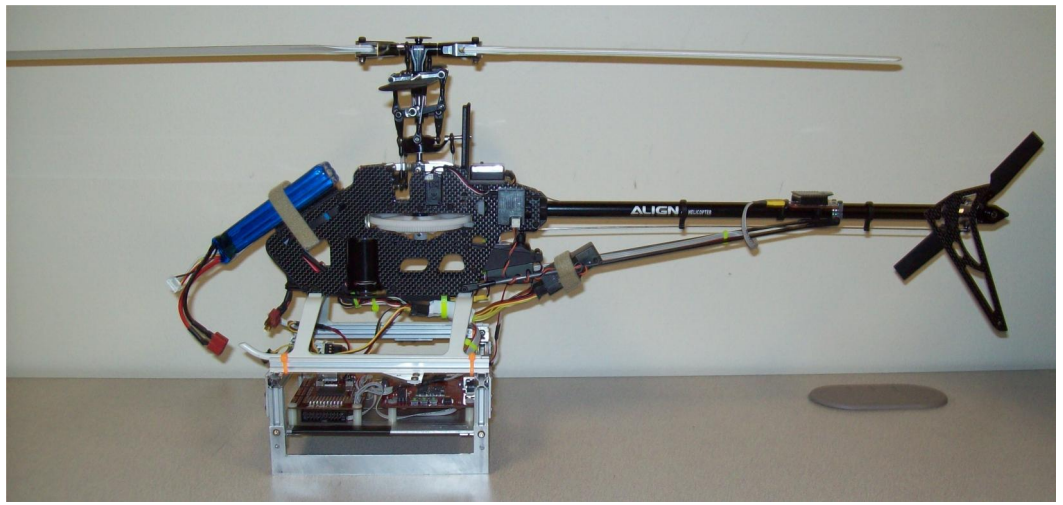


UNIVERSITY OF DENVER

Unmanned Systems Applications

- Unmanned Aerial Vehicle (UAV):
  - ➢ Current version uses 11 threads for autonomous operation
  - ➢ 21 threads available for application tasks





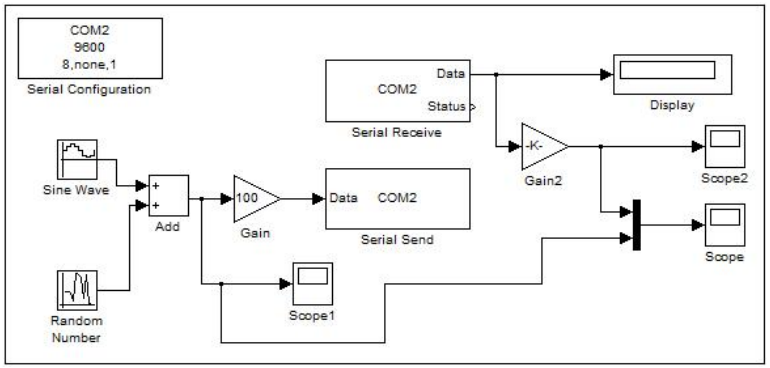
UNIVERSITY OF DENVER

Evaluation

- To demonstrate that XMOS is capable of handling multiple threads without losing the real time ability, a kalman filter (KF), SHA-2 encryption and the Floyd-Warshall algorithm were implemented and added to the Base UGV system;

  - ➢ To reinforce the real-time capabilites the remaining tasks were also added into the system running an infinite loop (i.e. consuming as much CPU as possible)

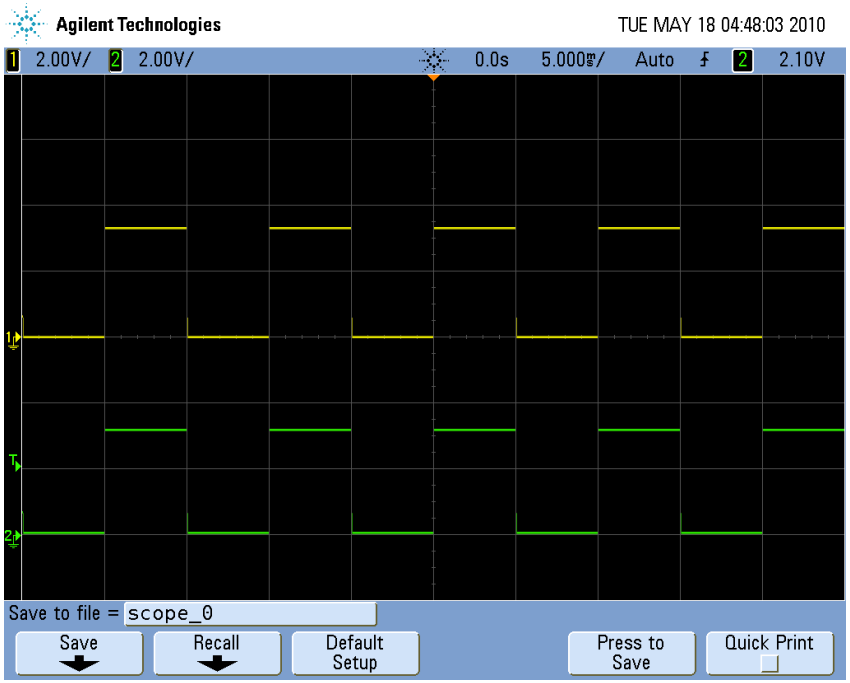
  - ➢ The KF also interacts with a MatLab/Simulink block using UART communication (hardware in-the-loop with XMOS platform)

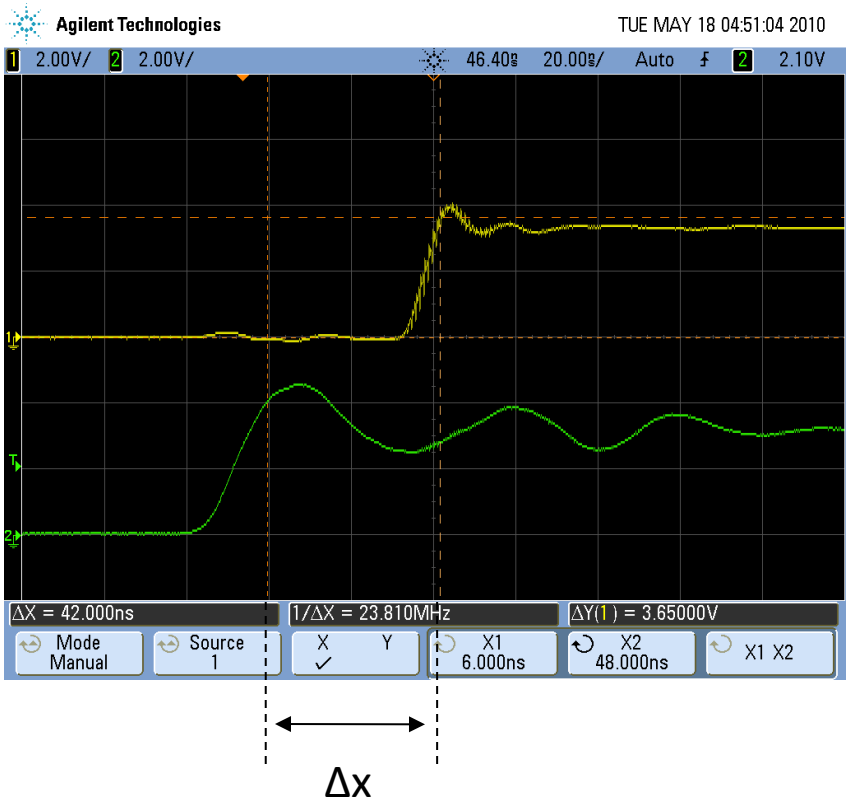


UNIVERSITY OF DENVER

Evaluation

- Results:
  - ➢ XMOS I/O interaction (reaction time of XMOS to a pulse)



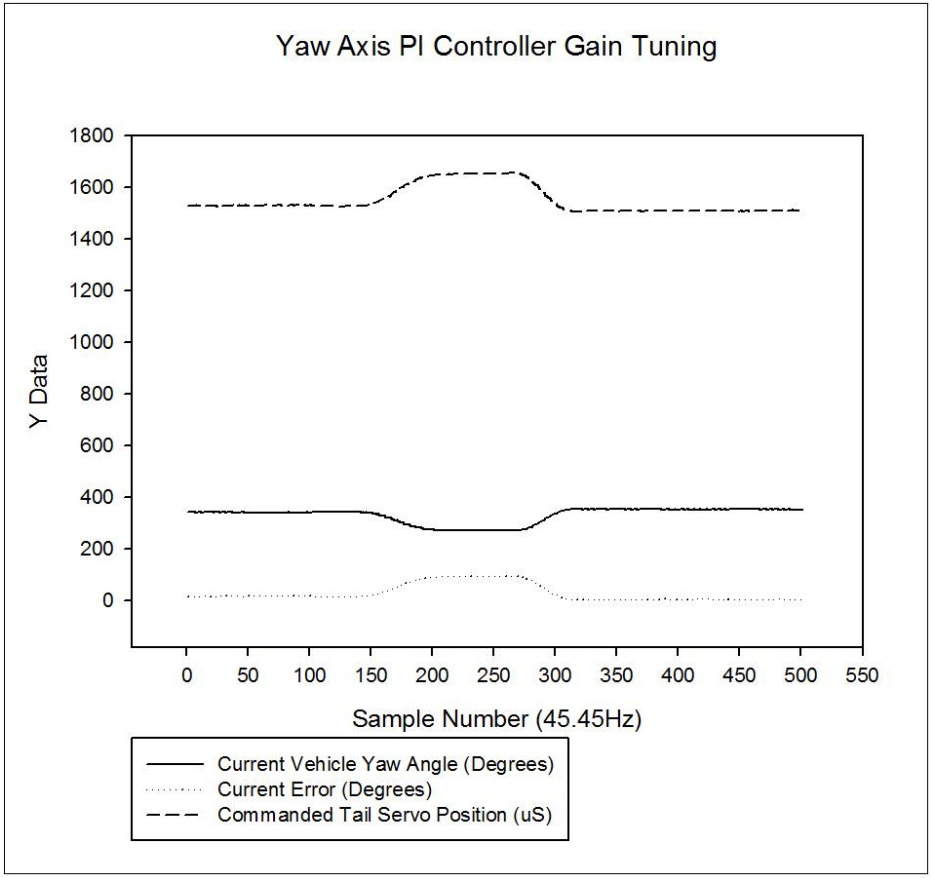


  - ➢ Δx = 42 ns (23.81 MHz)

UNIVERSITY OF DENVER

Evaluation

- Results:
  - ➢ UAV yaw axis controller tunning:



UNIVERSITY OF DENVER

Conclusions

- The proposed technology has several advantages over other conventional architectures:
  - Scalability
  - Hard real time
  - Fast I/O interaction (10 ns of resolution)
  - Compatible with standard languages (C and C++)
- Several algorithms were tested simultaneously to demonstrate that XMOS is capable of performing real time thasks
- It is also possible to perform hardware in-the-loop (e.g. MatLab/Simulink)

UNIVERSITY OF DENVER