## Title
Leader-Follower UAVs for Formation Testing



Authors
Rabinovich, Sharon
Elkaim, Gabriel

Publication Date
2016-05-11

# Leader-Follower UAVs for Formation Testing

Sharon Rabinovich, & Gabriel H. Elkaim
srabinov, elkaim @soe.ucsc.edu

## Introduction

- Many aerial missions consist of various different tasks.
- Unmanned Aerial Vehicle (UAV) has a greater operational capability than a single manned aerial vehicle.
- Multi-Vehicle systems have the ability to share tasks and therefor accomplish the mission objectives with greater efficiency.
- Ground Control Station (GCS) relay real-time information between UAVs (centralized system)
- UAVs transmit real-time information between group members (decentralized scheme).
- Formation flight testing base on three components: a 'Leader' UAV, a 'Follower' UAV and a GCS.

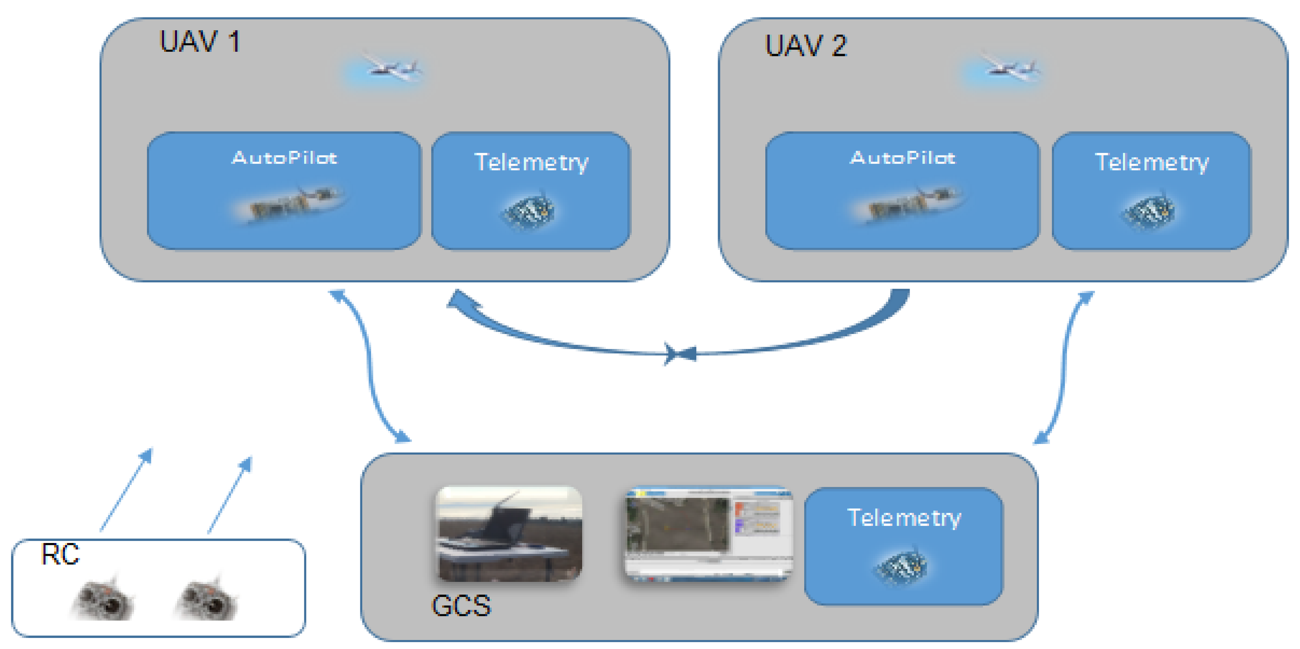


**Figure 1:** Top Level Formation Testing System Diagram

## Implementation

- Architecture to support Multi-UAV flight formation[2].
- Utilized a centralized and a decentralized scheme.
- Enable coordination and information sharing.
- UAV role is dynamic during the mission.
- The implementation includes a manual mechanism in GCS.
- GCS operator choose 'Leader' UAV and assign all the others as 'Follower' UAV. It will be initiated in future by the guidance system algorithm.

Figure 1 shows the top level integration design. Two UAVs utilize communication through GCS or directly between them (using XBees transceivers). Since our flight includes manual remote control, we also have RC controllers and receivers which are integrated in the UAVs.

Figure 2 shows the outcome of the integration with the auto-pilot as our basic real-time components, the UAVs platforms and GCS a moment before performing a field-test.

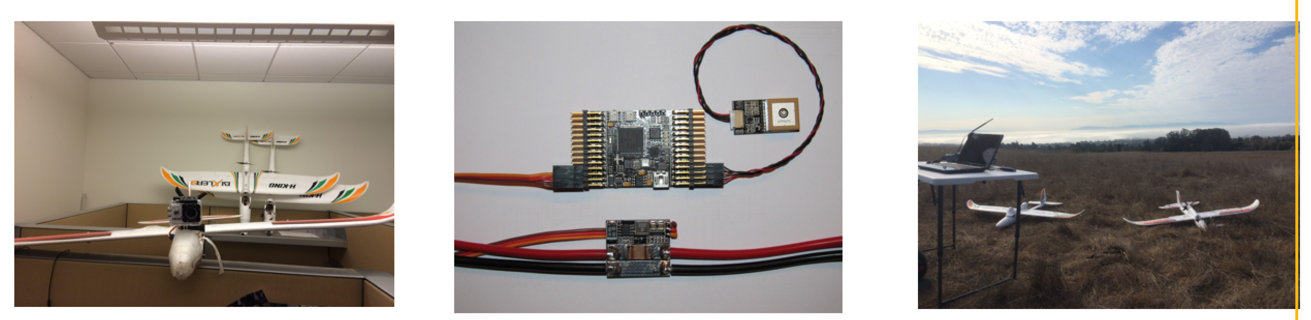

**Figure 2:** Hardware in the lab and in the a field-test

- Multi-UAVs system are very difficult to debug during the development or to analyzed after executing cooperative mission.
- Design includes hardware in the loop simulation (HIL).

**Figure 3:** Hardware in the loop (HIL) of single UAV with QGC and X-Plan simulator

Figure 3 shows the integrated development environment we use for HIL. The HIL being used to execute the full configuration of the UAV's hardware without actually fly the platform.

- Testing with all the hardware components (AUAV3 board[3], servos, power supply, telemetry and radio control).
- X-Plane simulator software provides the dynamic environment of the airplane model.
- X-Plan outputs physical parameters to another software, which translate and inject them to the real-time auto-pilot software (MatrixPilot[4]).

## Results

- Successful field tests results.
- Examine a different level of autonomous control.
- Run same mission plan for a single UAV as for Multi-UAVs (four way-points).

**Figure 4:** Single UAV flight performing mission plan (as it presented in the GCS)

Figure 4 shows snapshots from the GCS while performing the flight. The UAV (Bixler2) executes the mission plan and follows the given way-points with a resulted trajectory from the guidance algorithm.

- Examine the integrated system in a basic formation flight.
- Initiate the formation execution. Figure 5 shows sequence of position state for each UAV. The 'Leader' (in red color), tracks the default trajectory and the 'Follower' (in blue color) updates the mission plan with a new way point of the current 'Leader' position in 1Hz. The updates transmitted by the GCS to all the 'Followers' members. The resulting trajectories demonstrate, that the system can be scale up and can support different type of formation guidance algorithm.

**Figure 5:** Two UAVs in Leader-Follower configuration

## Conclusions

- Design for local data sharing and centralized scheme.
- Most of the transceivers tend to fail.

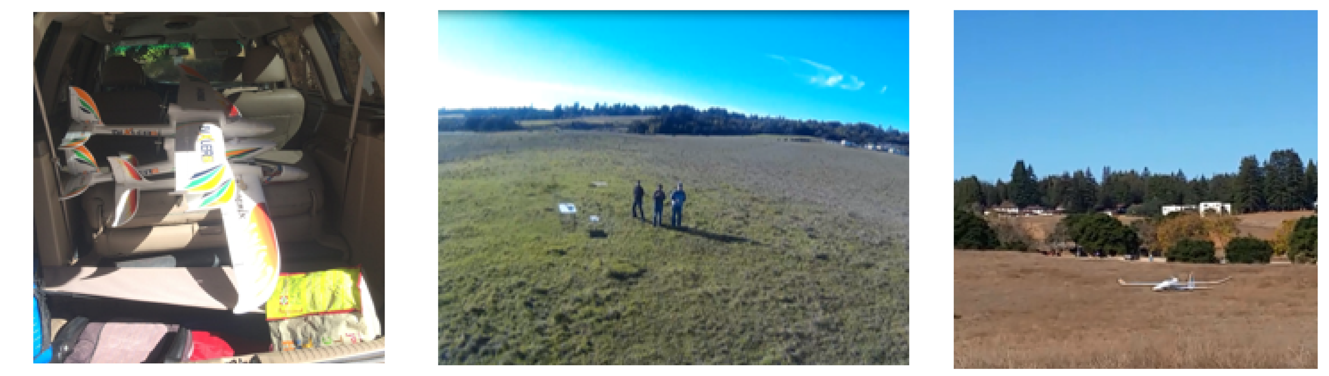

**Figure 6:** Field Test in UCSC - Before and After

From the implementation described and resulted field-tests one can conclude the following:

- This test-bed allow us to examine different types of communication topology and guidance systems to obtain UAVs flight formation.
- This development offered fast and satisfactory integration provided by components of the shelf (COTS): Airplane models (Bixler2), Auto-Pilot board (AUAV3), Auto-Pilot open source software (MatrixPilot) and GCS open source software (QGC).

## References

[1] Ren, Wei and Beard, Randal W, *Distributed consensus in multi-vehicle cooperative control*, Springer, 2008

[2] Beard, Randal W., and Timothy W. McLain. *Small unmanned aircraft: Theory and practice*, Princeton university press, 2012

[3] http://arsovtech.com/ *AUAV3 Auto-Pilot*, Web, 2016

[4] https://github.com/MatrixPilot/MatrixPilot/wiki *MatrixPilot Auto-Pilot*, Web, 2016

**For more information visit:** www.soe.ucsc.edu/˜srabinov , www.soe.ucsc.edu/˜elkaim