A Controlled Towed Vehicle for Air-Sea Interaction Measurements

Djamal Khelif[1], B. Bluth[2], Haflidi Jonsson[2], J. Barge[3], Eric Zivko[3], and Ryan Yamaguchi[1]
[1]Univ. of California, Irvine, CA; [2]Naval Postgraduate School, Monterey, CA; [3]Zivko Aeronautics Inc., Guthrie, OK
dkhelif@uci.edu

Introduction

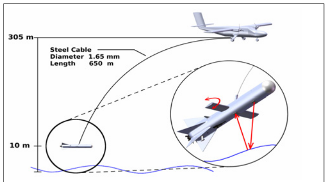
We have used existing target drone technology and **improved it** to develop the Controlled Towed Vehicle (CTV), a 0.23 m diameter and 2.13 m long drone that is capable of controlled flight as low as the 10-m canonical reference height above the ocean. The CTV uses an advanced autopilot and radar altimeter to actively maintain a user-set height above the sea via a controllable wing. We have instrumented the CTV with high fidelity and high bandwidth instruments to measure the means and turbulent fluctuations of 3-D wind vector, temperature, humidity, pressure, CO2 and IR sea surface temperature. Data are recorded internally at 40 Hz and transmitted to the tow aircraft via dedicated wireless Ethernet link. The CTV accommodates 45 kg of instrument payload and provides it with 250 W of continuous power through a ram air propeller-driven generator.

Manned aircraft operation at low-level boundary-layer flights is very limited. UASs and dropsondes are alternates for near the ocean surface measurements. However, dropsondes have limited sensor capability and do not measure fluxes, and most present UASs do not have the payload and the low-flying ability in high winds over the oceans. The CTV therefore, fills a needed gap between the dropsondes, manned aircraft and UASs to obtain in situ flux measurements near the ocean surface safely and in **an essentially non-intrusive way.**

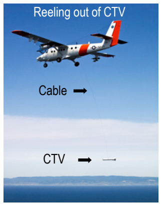
Motivation

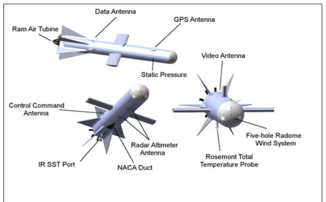
- Lowest flight level over the ocean for research aircraft is ~30 m (or much higher for some operators), thus the need to extrapolate the measurements to the 10-m reference height.
- Monin-Obukhov similarity theory applies to the constant- fluxes surface layer and profiles functions used were obtained from overland data (Kansas Experiment 1968).
- Even 30 m may be above surface layer in some BL flows such as developing gap outflow close to shore or very stable BL as in CBLAST-Low.
- Obtain simultaneous MABL measurements from two levels (e.g., in and below clouds).
- Make turbulence measurements in inhospitable high-wind marine surface layer possible while the tow aircraft flies safely above.
- Ships are too slow and, like fixed buoys, cannot sample cross-wind turbulence features like rolls and are prone to flow distortions and wave-induced motion.

CTV Control & Instrumentation

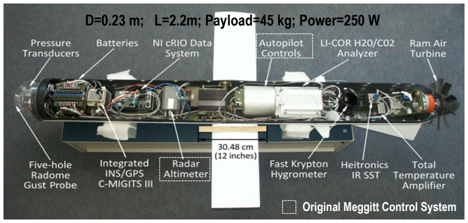


Radar height-keeping Concept





CTV External Anatomy

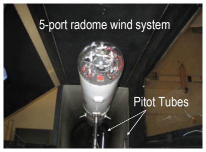


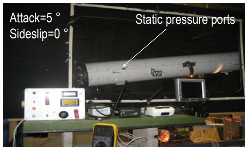
CTV Internal Anatomy

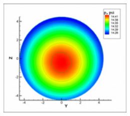
CTV Flight Safety

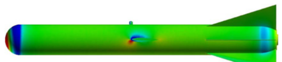
1. Cable "natural" lift: when enough cable is reeled out, its resultant lift force balances the weight of the CTV and prevents it from going further down. The active control system has to be engaged to pitch down the wings forcing the CTV further down to the commanded height. If malfunction, wings auto-set to neutral and CTV climbs promptly.
2. Operator-set minimum height below which control disengages and CTV climbs.
3. Real-time display of analog video from CTV nose camera in tow aircraft cabin.
4. Twin Otter nose radar detects ships, obstacles, etc…
5. Weak link on the CTV end of the cable breaks when cable tension is too high
6. Automatic cable cutter switches on flight deck and at CTV control station.
7. Manual cable cutter nearby winch system.
8. More than 90 cycles (release and recovery) without a single incident.

Wind Tunnel Calibration and CFD Modeling

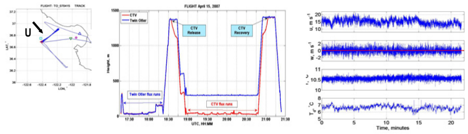


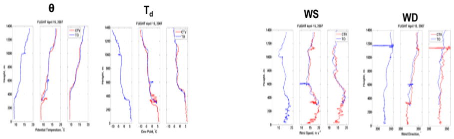






CTV Flights Results





Improved Flight Control with Piccolo Autopilot & MRA II Radar Altimeter

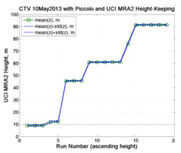
Piccolo SL Autopilot

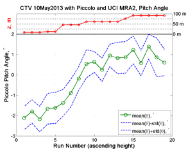
3 axis gyroscopes. 300 °/s
3 axis acceleration. 6g
Passthrough, RTK GPS
15 - 115 kPa Ported Pitot.
4KPa Differential (78 m s^{-1})
Size: 130 x 59 x 19 mm
Mass: 110 g (3.9 oz)
Power: 4 W
Supply Voltage: 4.5–28 VDC
T: -40 °C to +80 °C

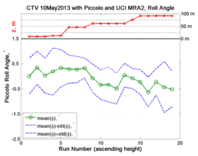
Radar MRA II Altimeter

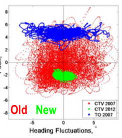
Range: 0.2 – 100 m
Resolution: 0.02 m
40° x 20° (3dB) Beamwidth

Size: 140 x 75 x 46 mm
Mass: 375 g (13.25 oz)
Power: 3 W (7W peak),
Supply Voltage: 9-32 VDC
Acceleration: 10 g
T: -40 °C to +55 °C

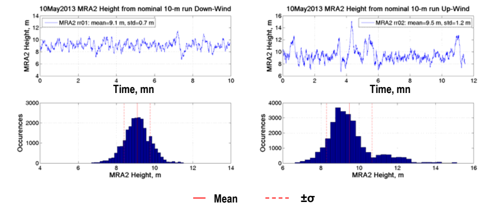




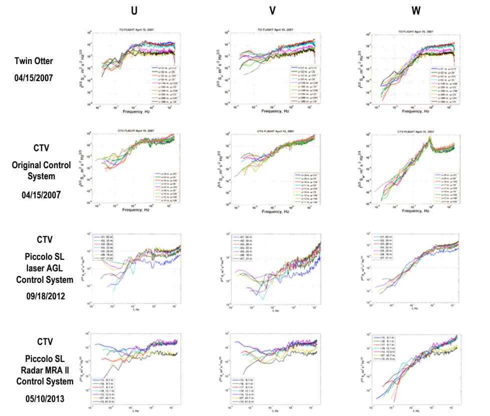




Improved Active Height-keeping



Improved Vertical Wind Component Spectra



Conclusions

- Towed drone technology is a viable means to obtain critical measurements near the ocean surface in high winds..
- New and improved control system solved the vertical wind motion contamination problem that was the CTV's Achilles' heel with the original Meggitt control system.
- CTV has more power and payload (no skimping on instruments) than most UASs.
- Other sensors can be added or substituted – atmospheric chemistry (fires, volcanoes, hazardous air contamination), aerosols, radiative transfer, waves, etc.
- Adaptable to larger research aircraft NSF/NCAR C-130 or NOAA/AOC P3 to obtain fluxes near the ocean surface while safely flying above.
- The CTV has had approximately 90 cycles (100 hours) without any mishap.
- New RF link system for real-time display of he analog video from the CTV nose camera was implemented and successfully flight-tested in early December 2014.
- CTV is fully ready for field deployment.

Future CTV Work and Projects

We will make near surface turbulence and fluxes measurements with CTV and the Twin Otter in October 2015 off Duck, NC during the ONR/NPS Coupled Air Sea Processes and EM ducting Research (CASPER) East experiment. We will modify and integrate onto the CTV a LI-COR 7200 for redundant fast humidity and use height data from radar and laser altimeters and DGPS to infer local wave height.

Acknowledgements

We would like to acknowledge CIRPAS and Zivko, Inc. crew and personnel who spared no effort to help us successfully develop the CTV and carry out the numerous CTV flights. UCI research work on this project has been funded by ONR grants N000140310305, N000140810438 and N000141210444.