UAV AGARDOGraph Status Update

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Naval Test Wing Atlantic (Retired)

Background

- Last NATO UAV test publication 20 years old
  - Outdated
- U.S. Naval Test Pilot School issued FTM-110
  - Written 2016
  - Reflected Global Hawk, X-47, Triton lessons learned
- AGARDOGraph proposed 2018
  - FTM-110 as start
  - Add more material

Background

- Inputs from
  - U.S. Air Force
  - U.S. Navy
  - NLR, the Netherlands
- Some overlap
  - Editorial decision to let each chapter speak for itself
- Currently in public release review chain

Chapter 1 – Historical Perspectives

- 5 generations of UAVs.
- Modern large UAVs are 4th generation.
- 5th generation capabilities are in technology development.
- Capable of useful military missions, including ISR and strike.
- Beware of overambitious marketing people signing the technology up to do what it can't.

Chapter 2 - Safety

- Minimum of 2 links from the ground station to the air vehicle.
  - If you're down to one link, troubleshoot.
- Be a good neighbor when it comes to airspace.
- Don't rely on autonomous emergency procedures to solve problems.
  - Don't test in flight, use the Systems Integration Lab.
  - Do observe responses to failures in flight.
- Flight Termination Systems add one risk to mitigate another. Have a "What-If" policy for emergencies.

Chapter 3 – Test Team Daily Ops

- Stay on good terms with civil airspace authorities.
- Testing large UAVs is a job for properly trained aircrew.
- Testing will demand a large number of properly trained Test Event Directors.
- Test card decks require time/resources to prepare.
- Large UAV testing has a lot of parts that require disciplined communications.
- Multi-shift test flights will be routine for some designs.
  - Brief all shifts the day before, update for each shift just before taking stations.
- Manage test team tempo carefully.
- Debrief thoroughly.

Chapter 4 – Test Prgm Mgmt

- Early test planning is critical.
- Use test metrics that make sense, and won't swamp the test team to track.
- Manage overwork wisely.
- Expect operational deployment of test assets.
  - Plan and resource test program with this in mind.

Chapter 5 – SIL & Ground Testing

- UAVs require more ground testing than manned aircraft of similar complexity.
- The Systems Integration Laboratory (SIL) is a major ground test asset.
  - “Iron bird” for testing.
  - Used for development, troubleshooting, previews of high-risk tests.
  - Best practice is to have three of them.
- Stationary ground testing will be extensive.
  - Be sure to include testing the ground station.
  - Be sure to include testing the maintenance equipment.

Chapters 6, 7, 12 – Surrogates

- *Note: Had multiple inputs on this subject*
  - *And there's going to be briefs on it at this symposium*
- Sometimes, it is advisable to use testbed and surrogate aircraft and systems.
- General types:
  - "Flying SIL" for testing engines, radars, other sensors.
  - Experimental airframe to demonstrate new ideas.
  - Existing airframe controlled by test system.
  - Surrogates to refine tactics and procedures.
- Surrogate and testbed aircraft can save time and resources.
- Surrogate and testbed aircraft present unique issues.

Chapter 8 – Taxi Testing

- Buildup
  - Speed from ~5 kts to ~3/4 of takeoff speed.
  - Complexity from straight line to multiple turns.
- Duration will depend on maturity
  - Can take several months for completely new design.
- Takeoff abort is last test prior to flight.
  - Dress rehearsal
  - Need a flight clearance.
  - Very fast-paced.

Chapter 9 – First Flight

- One takeoff, one landing, no smoking holes.
- Limited scope.
  - 0.5-1.5 flight hours.
  - Conservative command envelope.
- Work with Public Affairs beforehand, they can be a valuable ally on the flight day.
- Be mindful of first flight traditions.
- Take lots of photos.
- **No first flight plan survives first flight, be ready to improvise.**

Chapter 10 – Stability & Control

- UAVs have a Command Envelope of commands that can be given to aircraft.
  - Treat expanding this as carefully as buildup in altitude, G, airspeed, etc.
  - Have a way to get out if one doesn't work right.
- Altitude/airspeed/G/configuration expansion is similar to manned aircraft.
  - Change only one parameter at a time.
  - Some UAVs have very narrow envelopes, not much expansion in that area.
- No "stick free" stability & control characteristics.
  - Use closed-loop inputs to get data.
  - Need engineering test commands (ETCs) to do some tests.
  - ETCs need to be identified and in software requirements ~ 2 years before flight.
- No handling qualities, computers work the controls.

Chapter 11 - Performance

- Generally like manned aircraft.
- High-precision navigation systems on UAVs make some tests easier.
- Limited flight envelope may significantly impact test approach.
  - Work with what is available.
  - Brute force methods will work when nothing else will.
- Mission relation is essential.
- *Pay attention to the brief on the Triton performance test methods*

Chapter 13 – Carrier Suitability

- Significant challenges for carrier operations.
  - Many mode changes.
  - Integrating a datalink/command-and-control architecture in a heavy EMI environment
- Deck handling comes first.
- Catapult launches.
  - Watch the guidance mode transitions.
- Arrested landings.
  - Last ~30 seconds critical.
  - Watch the guidance mode transitions.
- Off-Nominal Arrestments.
  - Define requirements for flight control laws early
- Superior proven guidance and control performance of the UAV may eliminate/reduce the requirement for traditional (manned) off-nominal arrestments

Chapter 14 – Airworthiness Certification

- *Subject of a paper this afternoon*
- *So I'm not going to steal his thunder*

Chapter 15 – LTA Systems

- Lighter-than-air and UAV technologies both suited to long-endurance missions.
- Basic materials on LTA technologies and approaches are in TM-94-1-FW.
- Don’t get too aggressive on first flight.
- Airships have some unusual flying qualities.
- Performance generally like fixed-wing, but with static heaviness substituting for gross weight.
- Expect to see more LTA systems among the next generation of unmanned aircraft.

Chapter 16 – Human Factors

- Human factors design is a major challenge.
- Moving map is primary situational awareness display.
- Primary Flight Display is a supplement/control input.
- Caution and Warning systems can be as much problem as solution.
- If an input device has multiple functions, be wary of mode changes.
- Watch the control transfer process.
- Test the ground support equipment.
- Early involvement by the test team prevents deficiencies.

Chapter 17 – Communications Links

- 3 major families.
  - Line-of-sight.
  - Over-the-horizon direct from ground station.
  - Networked over-the-horizon.
- Different links have VERY different characteristics.
- Test each link alone, then together.
- Test buildup.
  - Ground stationary.
  - Ground taxi.
  - In flight.

Chapter 18 – External Connectivity

- Ground stations have many connections to outside world.
  - Information and tasking in.
  - Intelligence products out.
- Major test area for UAVs with ISR missions.
- Test buildup.
  - Each path independently at light load.
  - Each path independently at full load.
  - Repeat with multiple paths at once.
  - Test incoming as well as outgoing.
- Security is major area of test.
  - Can avert major issues if precautions taken early in design phase.
  - Systems physically side-by-side may be on completely separate nets.

Chapter 19 – Mission Planning

- Mission plans very complex.
  - Major area of test.
- Test by planning missions.
  - Ease/time required.
  - Accuracy and correctness of mission plan.
  - Mission-relate results.
    - Fleet operators may not be as proficient.
    - Fleet operators may draw on pre-generated libraries for some portions.
- Dynamic mission replanning is theoretically possible.
  - Cautious buildup recommended.

Chapter 20 – Aerial Refuelling

- Aerial refuelling potentially very useful.
- Significant technical challenges.
  - Changes in guidance modes.
  - Navigation relative to tanker.
  - Navigation relative to drogue.
  - X-47B solved, refueled successfully.
- Test approach.
  - Watch the guidance mode transitions.
  - Test breakaway procedure before connection.
  - Connection.
  - Fuel transfer.
  - Disconnect and resume mission.
- Rotary-wing should be similar approach.

Chapter 21 – Small UAV Testing
Chapter 22 – Highly Autonomous Systems

- *There's a whole brief on these two chapters alone, I'm not going to step on it.*
- *Besides, this brief is running long as it is.*

Chapter 23 – Training Systems

- UAS presents a different set of training challenges due to the lack of traditional cockpit cues.
- The goal of simulation is to support the transfer of knowledge and skills to the student.
- UAS training systems have unique characteristics compared to manned aircraft systems.
- UAS trainers are complex integrated systems.

Chapter 24 – Weapons Separation

- It's much like manned aircraft.
  - Analysis
  - Fit checks
  - Captive carriage
  - Weapon interface with airframe
  - Weapon interface with ground control station
- Don’t underestimate the safety risks.
  - What happens when things go right?
  - What happens when things go wrong?

Chapter 25 – Future Developments & General Conclusion

- Unmanned aviation will be part of the future
- Expect to see UAV capabilities creeping into manned aircraft
- 'Loyal Wingman' and swarming will present challenges to testers
- This is the frontier of flight test

Status

- Writing – Complete
  - 226 pages in draft form
- Review for public release – In progress
  - Some issues with editor being retired
  - May need help motivating reviewers
- Timeline – Summer 2022?

Questions?