**Two Waypoint Scenarios**

**General Description** of the auto-pilot, waypoint, mission plan assumptions used in the Waypoint scenarios. A mission plan has been entered and accepted into the autopilot that includes 5 waypoints. Auto-pilot is turned and order to Follow Track using the track created from the mission plan. The aircraft is traveling between waypoints #2 and #3. Waypoint #3 is defined by X/Y position (Lat/Long) [and optionally altitude and time of arrival (TOA)]. A track between waypoints #2 and #3 is calculated by the auto-pilot resulting in a planned course and speed between the two waypoints. The auto pilot compares aircraft position to the intended position along the track and adjusts course and speed to achieve the intended track. Note that aircraft heading is often different than course and aircraft course/speed/elevation may be slightly different than track course/speed/elevation due to external effects (wind, et .al) and sensor variances. The auto-pilot calculates cross track error (XTE) – the distance between aircraft position and intended track position - and uses smoothing settings (abrupt or gradual) to make course and speed corrections to get back onto the intended track. When the aircraft arrives at a waypoint, the auto-pilot maneuvers the aircraft to achieve the track to the next waypoint.

Operationally, an operator may turn off the autopilot, and then a) fly manually, b) enter new course and speed, c) enter a fly-to-point (FTP). He may then return to using the auto pilot by 1) Return to track (RTT) [turns auto-pilot back on and uses smoothing settings to return to the track] or 2) Go To The Waypoint to create a track to a waypoint for a direct flight to the next waypoint after which he will return to the original track for the remaining waypoints. There may also be a Divert To Avoid function that is used to leave the track a new heading/elevation for a period of time/distance and then return back to track without turning autopilot off.

**SCENARIO A1 - Waypoint, Off Track to**

Narrative description of Intent (Result)

The aircraft is not on track to the next waypoint and auto-pilot is not correcting sufficiently to regain the track.

DB: good to assume that the UAS is operating autonomously for this scenario, or else the operator can gain control, and fly it where it is supposed to go. And even if GPS is spoofed, there will likely be some noticed discrepancy by the human operator.

Orientation and Observation factors (indicators)

XTE – excessive, not reducing (growing or steady XTE), persistent

Heading – large divergence from track course (5-10 degrees?)

Speed – large divergence from track speed (50 knots?)

Altitude – large divergence from track altitude (500 feet?)

Wind – very high wind (true wind calculated from onboard sensors)

Autopilot (off/on), Manual, Return-to-Track, GoToWaypoint, Divert modes

Radar Altimeter – divergence from measured barometric pressure and terrain elevation.

Disagreement between navigation aids (GPS, INS, VOR, VORTAC, sunlines)

Control surface positions (indicators/instruments) – differ from auto-pilot orders

Engine throttle (indicators/instruments) – differ from auto-pilot orders

Change in mode/availability of navigation inputs (i.e. switching GPS from primary to off or secondary)

DB: Good list above of inputs, especially all the varied navigation methods. Should be incorporated into ADIDRUS models. The discrepancies from above that we actually notice will be dependent on which specific attack is used for the demo.

Attacks (Causes)

Disable. Impair, offset control surfaces

Disable. Impair, offset engine orders

Disable. Impair, offset elevation, altitude and windspeed sensors

Disable**. Impair, offset Navigational inputs (GPS**, INS, dead reckoning, terrain following, VOR, RF beacon, cell tower, etc.

Todo: Add that attack would be via DDS

Disable. Impair, offset Mission Control Computer inputs, calculations, algorithms, outputs

Disable. Impair, offset Autopilot inputs, calculations, algorithms, data tables (plans) outputs

DDS manipulation

DB: for the purposes of a demo, let’s choose one of the above as the adversary’s attack. GPS spoofing is the obvious one. Another would be that the autopilot’s outputs don’t point the aircraft in the right direction; there would be a constant conflict between the mission plan and the actual progress towards a waypoint.

Remedies

Alert operator to switch priority of navigational inputs

Alert operator to switch progressively out of Follow Track to Go To Waypoint, to Manual (autopilot off)

Try cyber probing, fuzzing, etc. to identify the point of attack

DB: What if there is no operator, and we’re operating in autonomous mode? Possibly switch over to dead reckoning or other navigational aids depending on the required precision of the mission – we might be able to finish it.

**SCENARIO A2 - Waypoint, Manipulation of**

Narrative description of Intent (Result)

Aircraft is on track to the next waypoint but the waypoints in the autopilot have been altered to a different track than originally entered from the mission plan.

Orientation and Observation

Mission Plan disagreements with the auto pilot waypoints and tracks:

• Overall plan - Number of waypoint, total distance, time of arrival on station,

• Waypoints – disagreement in X/Y (Lat/Long) elevation, time of arrival

• Tracks – distance, course, speed

Attacks (Causes)

Auto-pilot track originally created from the mission plan is altered in the autopilot

Autopilot inputs or outputs are disabled, offset, impaired

DDS manipulation

DB: Need to decide how/where this is done. Is it sophisticated malware in the autopilot calculations? Some fake data in an underlying database? This use case, as currently proposed, should drive a huge error between the waypoint and mission levels of ADIDRUS.

Workshop: Not necessarily ‘interesting’ or complex from an ADIDRUS point of view, but is a good scenario to demonstrate other system components (AD-LIB and APG). We don’t know where the Malware lives and so may need to iterate through several response/diagnose scenarios to fight through the attack.

Remedies

Alert operator to switch progressively out of Follow Track to Go To Waypoint, to Manual (autopilot off)

Try cyber probing, fuzzing, etc. to identify the point of attack

DB: We probably need to do some thinking as a team about how much a human is going to be “in the loop”. If there is a human operator, it should make it much, much harder for malware to do anything to defeat the mission without being detected. (There’s always the option to have the UAV blow itself up)

TODD and JAMES were here