From Specification & Design Layout to Control Law Development for Unmanned Aerial Vehicles – Lessons Learned from Past Experience

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The first Unmanned Aerial Vehicles (UAVs) entered service in the sixties, but it has been only recently that their potential, particularly for military applications has become apparent. As in many other aviation sectors, development has been driven by military requirements, for which the operational success of the intended mission is the most important design criterion. For civilian use, the most important criteria are safety of operation, respect for the environment, economic in operation as well as successfully fulfilling its planned role. A successful design will have a clearly defined mission and flying characteristics, carefully considered design layout, redundancy of sensors and computers – triplex or sometimes quadruplex systems - modern guidance and control that is either a pre-programmed/remote controlled system or a pre-programmed/autonomous system.

The causes of system malfunctions leading to the loss of an aircraft are often not detected because data transmission to the controller ceases at a critical moment. Typical examples are quoted below:

- “The Global Hawk was in its landing sequence when there was a control surface malfunction immediately followed by a data link break. The communication link was quickly re-established, but then the aircraft was already in a flat spin, as part of its selfdestruct program, and unrecoverable.” – Aviation Week & Space Technology, Jan.7, 2002;
- “On 22 April, 1996, DarkStar AV#1 crashed on its second flight. A thorough investigation by an independent review team identified the accident’s cause as interactions between the landing gear and the vehicle’s inertia which caused an undamped oscillation, the so-called “porpoise”. The low moment of inertia exacerbates the pitch motions and the only damping was the tires, and any disturbances would cause the porpoise.” – Unmanned Vehicles, May 1998;
- “At least two of the three Predators downed in Afghanistan in September & November 2001 were lost due to icing of pitot tube, a problem that plagued the aircraft during operations in Balkans.” - Aviation Week & Space Technology, Nov.12, 2001.

In order to simulate or analyse these malfunctions a knowledge of the UAV’s performance characteristics and configuration is required. However such information is classified and not generally available. Limited performance data, overall dimensions, weights etc may be gleaned from published material, for example from technical journals, manufacturers’ publications and appropriate web sites.

Future designs must take into account experience derived from previous UAVs. Using the data sources given above, a data base has been set up for Global Hawk, Predator, Hunter and other UAVs. From this information it has been possible to compute and analyse a range of performance characteristics including flight envelopes, fundamental performance, natural modes of vibration, gust sensitivity and some dynamic responses. This has enabled some comparisons to be made. Additionally pro-spin tendencies have been analysed, but these are very sensitive to post-stall aerodynamic wing characteristics. Thus the so called tail-damping power factor (TDPF) and dimensionless difference of moments of inertia cannot be a reliable indicator of spin resistance.

Based on the above analyses, a series of recommendations has been formulated, including control law development, for the preliminary design and layout of a UAV optimised for a long endurance observation mission at either medium or high altitude.

Educationally there a number useful benefits that may be derived from this analysis and design activity. These include:

- How to search for data essential for a preliminary performance assessment from secondary sources. Students at Warsaw University of Technology given basic geometrical data are required to calculate performance and dynamic characteristics. Those at Kingston University working in design teams produce performance data for their preliminary designs which may be validated on a flight simulator.
- How to allow for uncertainty in data which may be unreliable.
- How to reconcile the design philosophy for manned and unmanned aircraft.

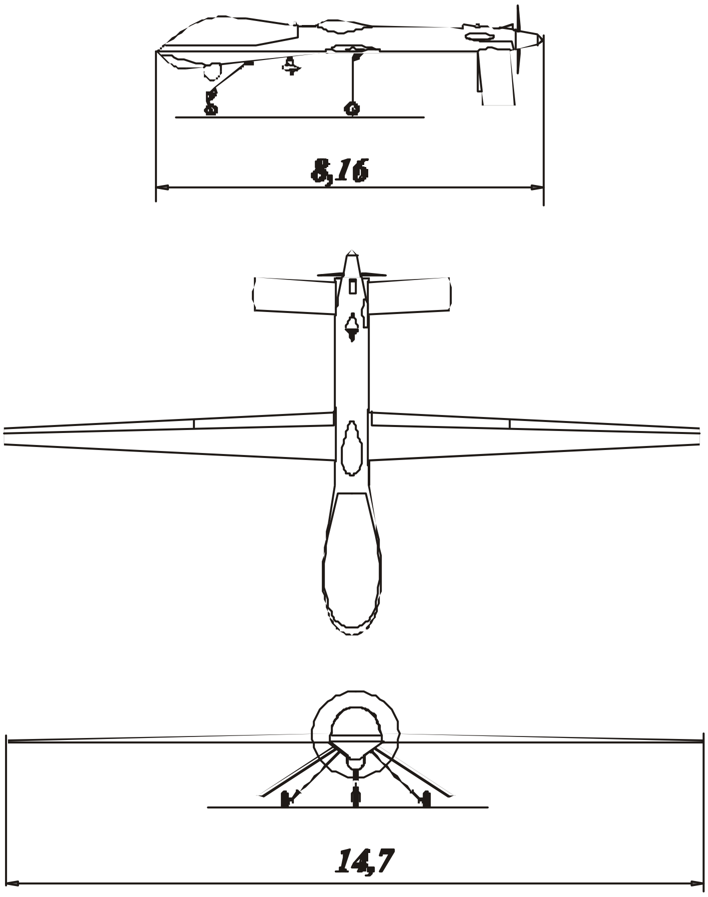

Figure 1 Predator RQ-1B – general arrangement

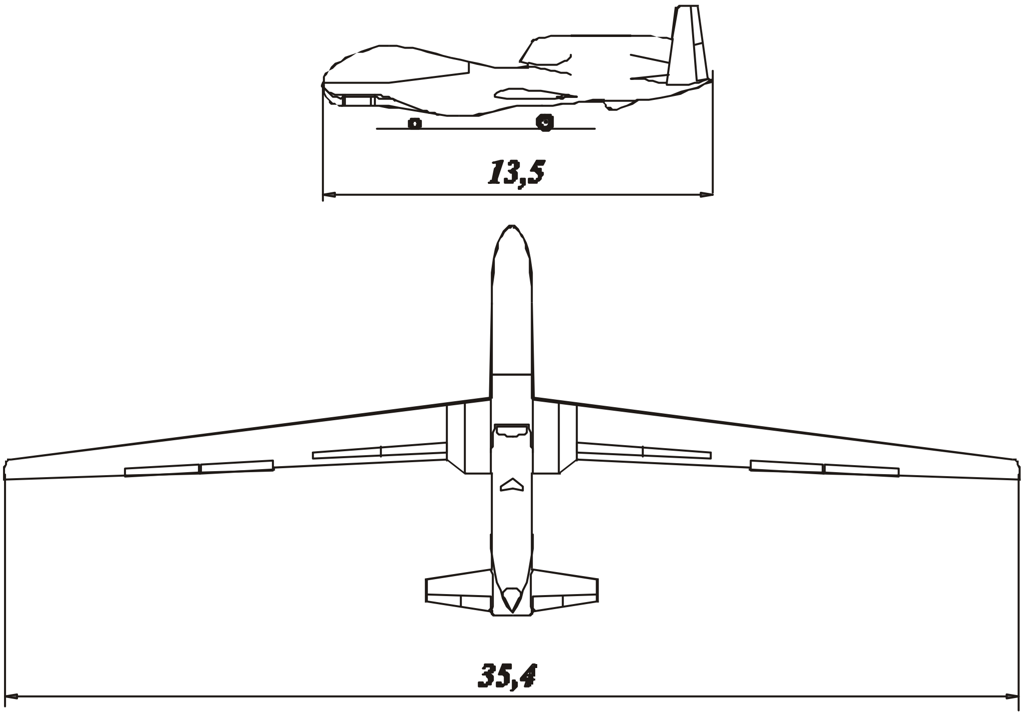

Figure 2 GLOBAL HAWK – general arrangement (configuration based on Website sources)

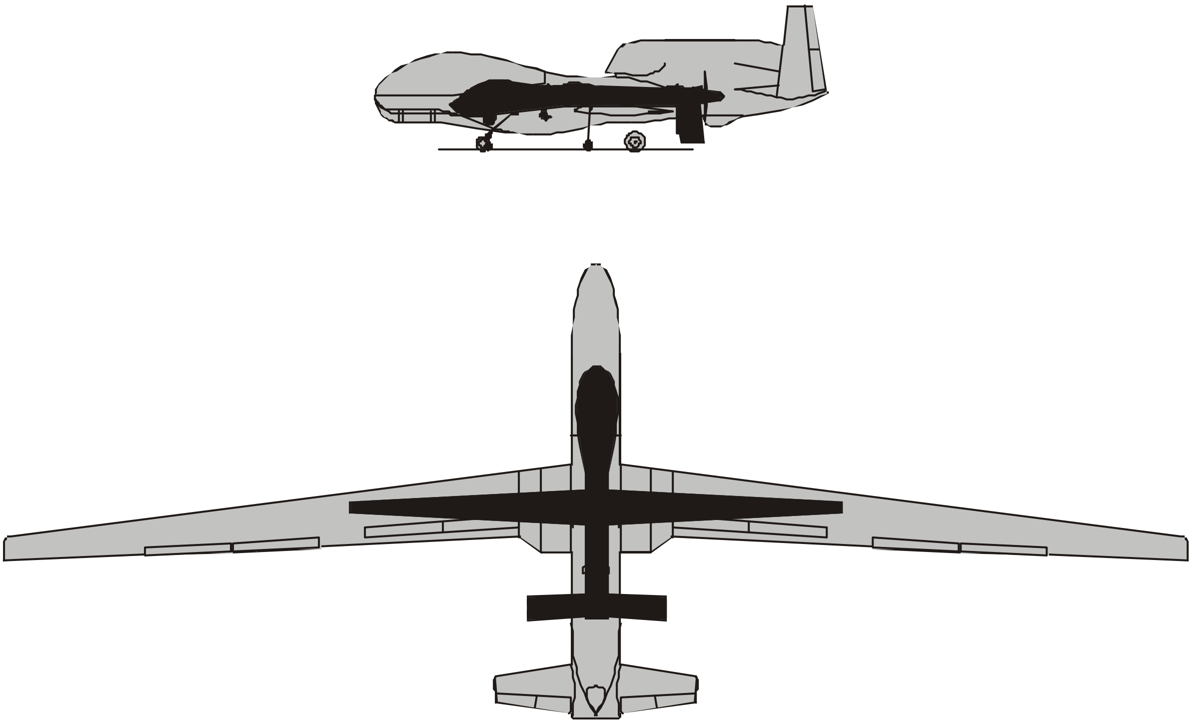

Figure 3 GLOBAL HAWK & Predator RQ-1B – comparison of view plans

GLOBAL HAWK (ES) - Flight Envelope

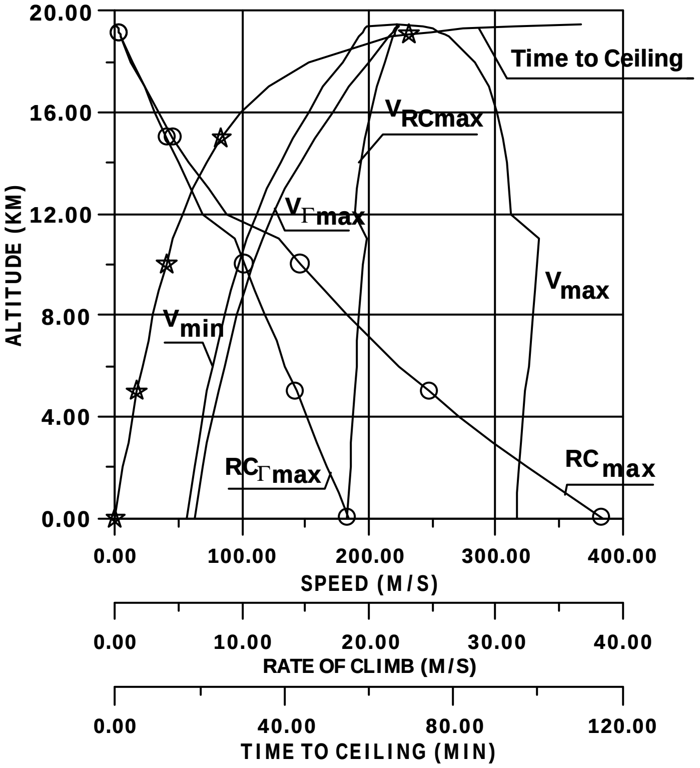

Figure 4 GLOBAL HAWK – flight envelope, time to ceiling, steepest & fastest rates of climb

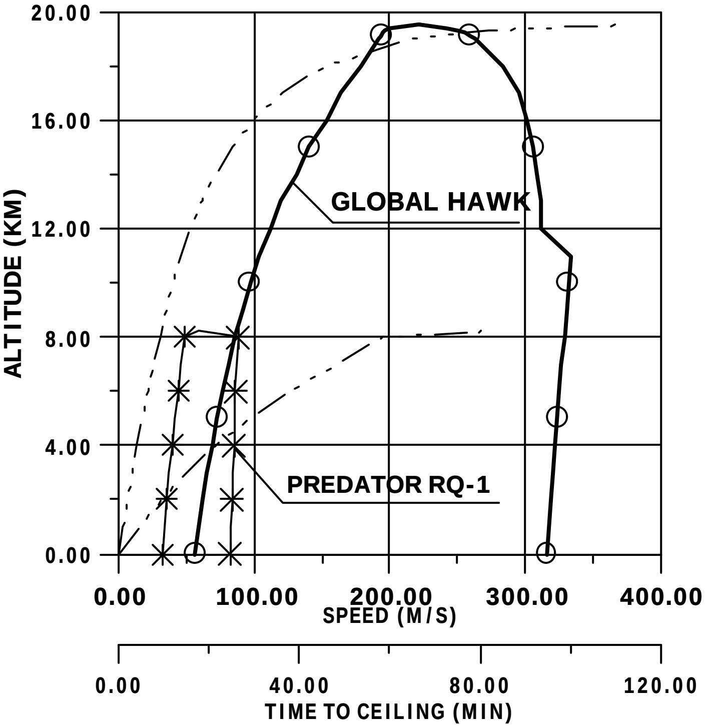

Figure 5 Global Hawk & Predator – flight envelopes

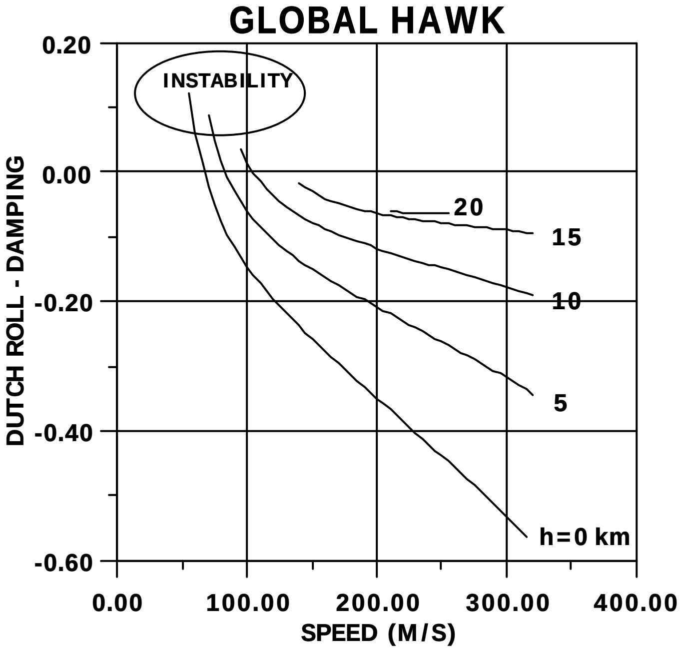

Figure 6 Local instability of Dutch Roll mode

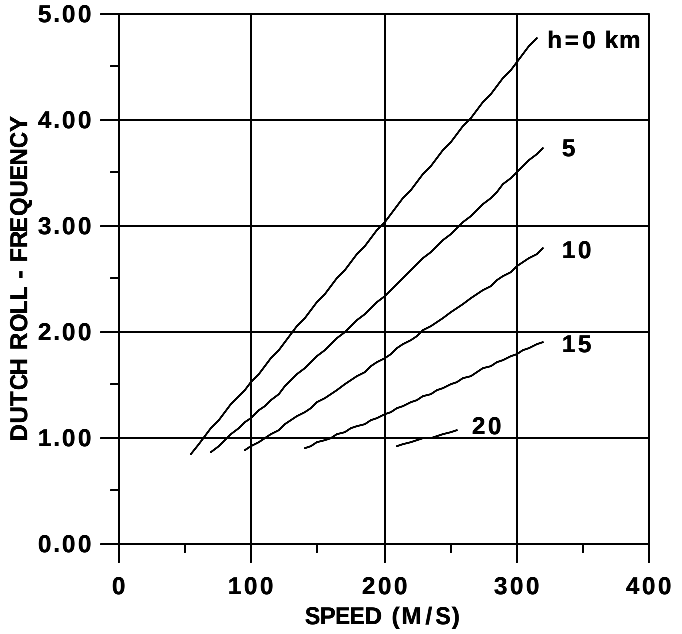

Figure 7 Frequency of Dutch Roll mode of GLOBAL HAWK

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