

A Multifaceted Investigation and Intervention into the Process of Flight Clearance for UAS Experimental Flight Test

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ABSTRACT

Unmanned aviation systems (UAS) acquired for US Navy for military roles are developed in the context of NAVAIR's rigorous and well-established policies, procedures and processes employed in the acquisition and development of manned aircraft. A key process is the preparation and approval of interim flight clearances (IFC) prior to flight test to ensure the aircraft is airworthy and thus safe to operate. Due to the perceived risks of UAS experimental flight test, the use of this process has been mandated for all Navy organizations, including use of commercially available UAS in research projects. This policy has proved to be a challenge, impeding and discouraging the use of UAS in research and experimental projects. Currently, the cost of compliance is unaffordable and IFC preparation and approval time are inconsistent with research cycle time expectations. The research reported here investigated the difficulties and advocates solutions devised through the application of systems engineering. In particular, a hazard and risk analysis tool exploiting Bayesian belief networks was developed and demonstrated in support of the interim flight clearance process for the the JACKAL VTOL UAS platform being developed for use in Naval Research Laboratory research flight testing.

CITATION: Millar, R., "A Multifaceted Investigation and Intervention into the Process of Flight Clearance for UAS Experimental Flight Test," *SAE Int. J. Aerosp.* 8(2):2015, doi:10.4271/2015-01-2385.

1. INTRODUCTION

1.1. Project Initiative

Unmanned aviation systems (UAS) for US Navy military roles are developed in the context of US Naval Air Systems Command (NAVAIR) rigorous and well-established policies, procedures and processes employed in the acquisition and development of manned aircraft. A key process is the preparation and approval of interim flight clearances (IFC) prior to flight test to ensure the aircraft is airworthy and thus safe to operate. "The IFCs provide temporary flight authorizations for aircraft systems operating in non-standard configurations, envelopes, or conditions [1]."

With the emergence and proliferation of UAS applied to naval research and experimental projects conducted both within and beyond NAVAIR test ranges, it was decided that a NAVAIR IFC was required for experimental UAS flight tests by Navy organizations. This proved to be a challenge, impeding and discouraging the use of UAS in research and experimental projects at Navy educational and research organizations. The application of the IFC process in weapons system acquisition is deliberate and painstaking, while experimental UAS capabilities are rapidly evolving, exploiting commercial off the shelf technologies for communication, navigation, controls and computing intelligence.

The technical data expected for experimental UAS IFC preparation is often unavailable (e.g., due to proprietary data restrictions), the mission and requirements tentative, and the responsible NAVAIR technical area experts (TAE) may be unfamiliar with the UAS

platform, the research environment and methods used. Overall, the cost is unaffordable and the response time is inconsistent with research funding windows and cycle time expectations.

The research project reported here was suggested by the US Naval Air Systems Command (NAVAIR) and sponsored by the Consortium for Robotics and Unmanned Systems Education and Research (CRUSER) to investigate the root cause(s) of these difficulties and recommend solutions. It was evident that the IFC process was rigorous and necessary to ensure safety. Thus the task was approached from a systems engineering perspective, focused on the IFC process and the disparate contexts in which it was being applied.

1.2. Interim Flight Clearance Context and Background

Flight clearance of naval air platforms is performed in accordance with NAVAIRINST 13034.1D, Flight Clearance Policy for Air Vehicles and Aircraft Systems [1], which establishes scope, policy, process and responsibilities for all Navy flight clearances, including UAS.

Preparing and processing interim flight clearances (IFC) is a critical factor in timely and effective flight test and development of Navy aircraft systems. The instruction defines three categories of IFC for UAS:

- Standard: for unrestricted operations based on standards similar to manned aircraft,
- Restricted: clearance for restricted flight environments to appropriate tailored standards and

- Developmental: UAS not fully designed or documented to accepted technical standards.

The instruction recognizes that different safety standards apply to each category but does not set any, stating “determination of airworthiness should be primarily based on compliance with standards chosen by the TAEs (Technical Area Experts), rather than verification of a system level mishap rate”. NAVAIRINST 13034.1D further states that the “flight clearance process involves an independent engineering assessment of airworthiness, safety of flight, and unusual risk” as detailed in the quotation below. [1] (pp. 6-7)

(a) Airworthiness.

Airworthiness determines the property of an air system configuration to safely attain, sustain and terminate (“complete” in the case of UAS) flight in accordance with approved usage limits. All manned aircraft must be airworthy. The UAS may have a lower level of inherent airworthiness and a higher probability of loss than manned aircraft. As such, UAS have been classified into three major categories ... so that the appropriate level of airworthiness criteria, engineering standards, and data requirements can be established.

(b) Safety of Flight (SOF).

SOF determines the property of an air system configuration to safely attain, sustain and terminate “complete” in case of UAS) flight (to include inflight or post-flight aircrew survivability), within prescribed and accepted limits for injury/death to personnel and damage to equipment, property and/or environment. The intent of assessing SOF is to show that the level of risk (hazard to the system, personnel, property, equipment and environment) has been appropriately identified by the Technical Area Experts (TAE), and accepted by the appropriate authority. All DON manned and unmanned aircraft systems must be safe for flight within acceptable levels of risk...

(c) Unusual Risk.

In some cases where risk is determined to be above normal, as determined by engineering or the National Airworthiness Team (NAT) for the intended mission (e.g., flight test, air show, Fleet use), a Hazard Risk Analysis (HRA) may be required and a Hazard Risk Index (HRI) may be included in the flight clearance. Prior to issuance of the flight clearance, those risks (including loss of aircraft) that exceed the acceptance threshold of the Technical Area Expert (TAE) will be briefed to, and accepted by, the appropriate risk acceptance authorities ... The TAEs will work with System Safety to include applicable Hazard Risk Statements, limitations, warnings, cautions, and notes in the flight clearance.

The defined IFC process relies on the knowledge and experienced judgment of the TAEs and other assigned personnel; no methods are prescribed to establish airworthiness, safety of flight and unusual risk. The Assistant Program Manager for Systems Engineering (APMSE)

and certified TAEs ascertain UAS airworthiness, estimate operational & technical risk and ensure System Safety and owner/sponsor acknowledgement of their assessment. The APMSE and TAEs determine IFC data requirements, review, edit and negotiate the IFC, and the TAEs define the airworthiness basis and limits. Thus considerable autonomy exists to tailor the criteria and process used to determine airworthiness of experimental UAS

The practices, knowledge and experience base used to process IFC for manned aircraft was only partially applicable to the challenge of flight clearance for UAS, for which necessary criteria, methods and information were ill-defined or unproven. The defined IFC process was presumed to be adequate, but it was anticipated that better tools (e.g. advanced methods for assessing system level hazards, probability of loss of aircraft, safety risk modeling and integrated laboratory and simulation trials) might be necessary to support the APMSE and TAEs in their critical roles & responsibilities for this evolving class of aircraft. The report of the initial phase of this research program [2] provides more detail on the NAVAIR IFC process and procedures.

Two unique aspects are combined in the research reported here: unmanned aircraft (remotely piloted and autonomous to varying degree) and the focus on experimental flight test, with an inherently greater level of uncertainty (mitigated by the possibility of restricted operations and other measures) and the variety and volatility of operational requirements, demanding speed in decision making and implementation. A key factor is that the risk to the flight crew and onboard test personnel is no longer a consideration, balanced against the inherent complexity and criticality of the UAS flight control system and reduced operator situational awareness and options for intervention to mitigate system failures.

NAVAIR suggested that NPS work with them to understand the context and needs of the IFC process, identify and analyze the challenges, then propose and demonstrate potential solutions. To address this challenge, the NPS CRUSER program funded a phased research program of three Systems Engineering Master's Capstone projects implemented over seven (7) academic quarters.

An NPS Systems Engineering Capstone project is a three academic quarter project that studies a real-world systems engineering problem confronting the Navy, or other challenges. Often, the problem concerns an engineering system, such as an aircraft, a weapons system, or an information system. This research project was unusual in that it concerned a process, the NAVAIR IFC process as applied to experimental UAS used in research by the Naval Postgraduate School (NPS). NPS Systems Engineering (SE) Capstone students were challenged to identify the reasons impeding satisfactory and timely IFC approvals, propose solutions and demonstrate their effectiveness. Three successive student teams, drawn from the pool of NAVAIR aerospace engineers and researchers concurrently enrolled in NPS Masters programs, defined & performed the project tasking.

NAVAIR invested a key resource: the time of their engineering managers and engineering specialists as active participants as stakeholders and TAE, including NAVAIR 4.0P (Airworthiness), as the final judge of a satisfactory IFC process.