Aircraft Type and Model Description

NASA DFRC 2007 Fire Mission
UAS COA Application Attachment

NASA Dryden Flight Research Center (DFRC) has procured from General Atomics – Aeronautical Systems Incorporated, an MQ-9 Reaper aircraft and a Ground Control Station (GCS). DFRC has assigned the number "NASA 870" to the aircraft and renamed it "Ikhana" (pronounced ee-kah-nah , a Native American word from the Choctaw Nation meaning intelligent, conscious, or aware).

In general, the aircraft is standard unmanned MQ-9 aircraft with a few differences. First, Ikhana has no weapon systems installed. Second, the MQ-9 Flight Manual indicates the standard NAV configuration is 3 EGI (Honeywell H-764 embedded GPS/INS units), but we believe Ikhana is configured with 1 EGI (Honeywell H764), 3 GPS (Novatel OEM4-G2 boards), and 3 INS (Honeywell HG1700 units). Third, the aircraft has some additional wiring and instrumentation systems to support NASA science research activities.

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1. **UAS System** – The Ikhana system can potentially have 3 components: (a) The Ikhana aircraft, (b) a "Launch and Recovery Element (LRE)" GCS, and (c) a Mission Control Element (MCE) GCS. For the 2007 Western States Fire Mission, the Ikhana GCS will act as the LRE and the MCE, and consequently, there will only be 2 components (aircraft and GCS).

   1.1. **Ikhana (MQ-9) aircraft** – General Atomics Aeronautical Systems Inc., Rancho Bernardo, California manufactures the Ikhana (MQ-9) aircraft. The aircraft are designed to be flown by a pilot or in an autonomous mode. Autonomous pre-planned responses may be overridden from the ground control station at the discretion of the pilot.

   1.2. **GCS** – The GCS functions as the aircraft cockpit. A single GCS is planned for use as the LRE and MCE. See Figure 1. The GCS can control the aircraft either within line of sight (LOS) or over the horizon (OTH) via a combination of satellite relay and terrestrial communications. Control of an aircraft may be passed between ground control stations at any time during the mission. For the 2007 Western States Fire Mission, there are no plans to pass control between ground control stations.

      1.2.1. **Launch and Recovery Element** (LRE) – An LRE will be used for launching and recovering the aircraft. After launching an aircraft the LRE will handoff control to the MCE to perform the specific mission. The LRE operators will communicate with airspace management authorities until handoff. LRE voice communications with ATC are provided by a single ARC-210 UHF/VHF voice radio relay through the aircraft with telephone communications available as backup.

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1.2.2. **Mission Control Element** (MCE) – The MCE provides aircraft and mission control during the enroute and on-station mission phases. The MCE need not be collocated with the aircraft at the operating base, although for the 2007 Western States Fire Mission, the MCE and the aircraft will be collocated. The MCE has communication links with the vehicle through two LOS (C-band) data links, and a Ku band OTH satellite communication (SatCom) data link. Voice connectivity with ATC is provided through aircraft relay via Ku SatCom data link with telephone backup.

1.2.3. **GCS Data Recording Capabilities –** The GCS has the 2 standard MQ-9 capabilities. The first records video and most data elements on Hi-8mm tapes for viewing at the pilot's workstation. The second capability records all data elements, but no video onto "data logger" files. These data logger files are routinely downloaded and stored for possible post-flight analysis.

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TYPICAL SYSTEM COMPONENTS

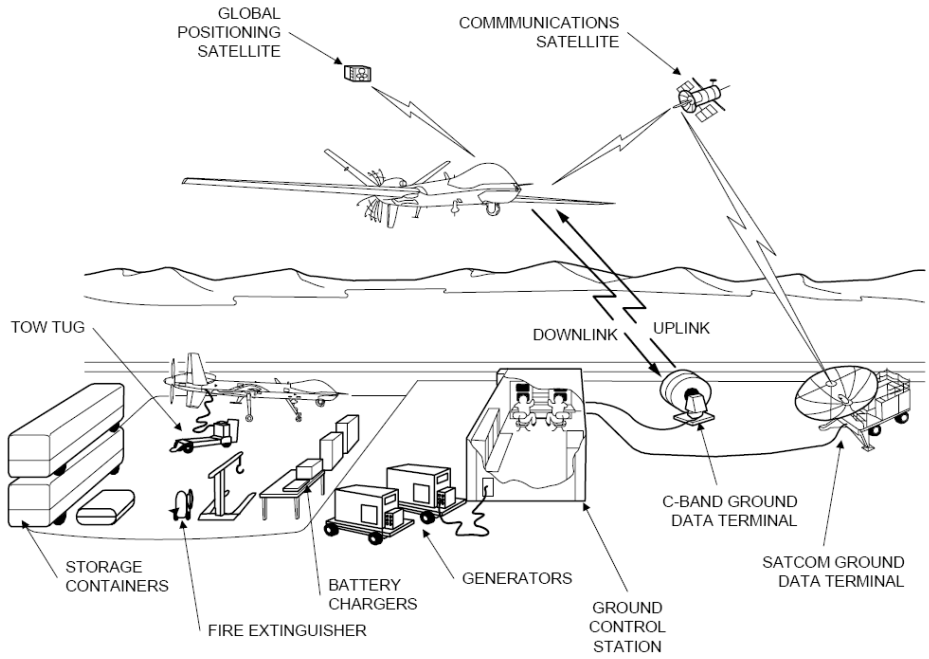

Figure 1

2. Aircraft Physical Characteristics.

2.1. **Aircraft dimensions** – Wingspan 66 ft, length 36 feet. See Figure 2 for Typical Aircraft Dimensions.

AIRCRAFT DIMENSIONS

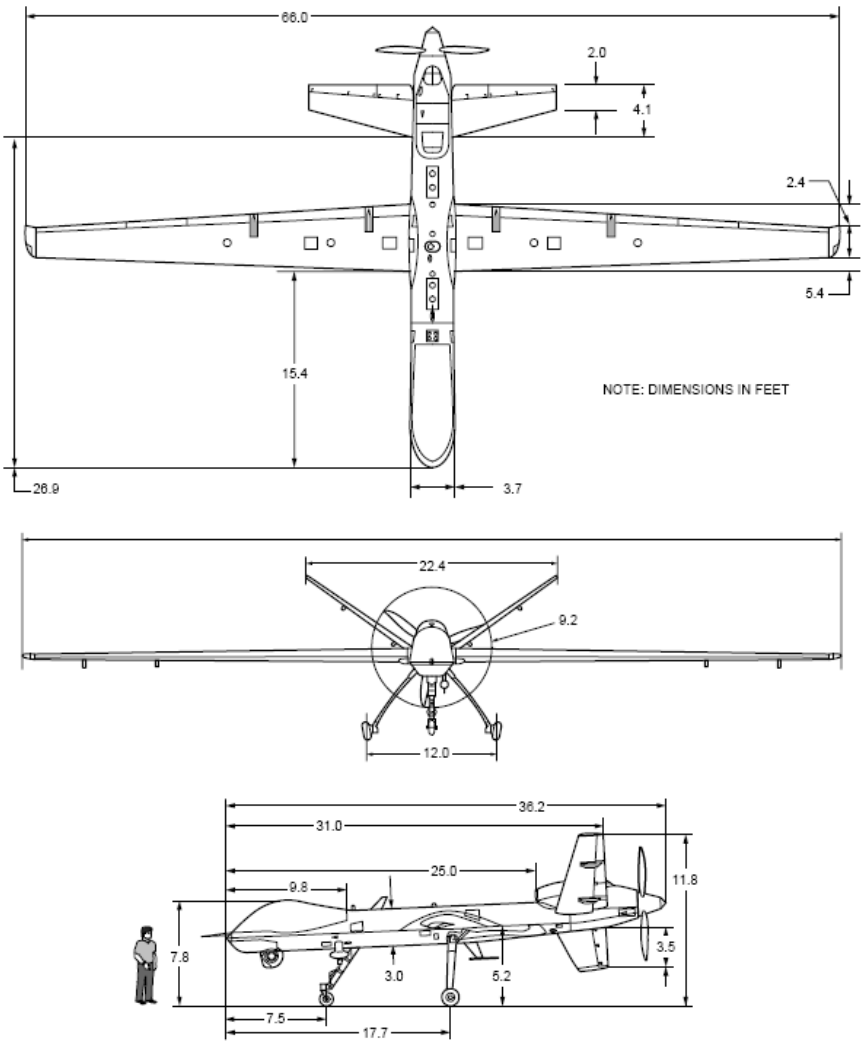

Figure 2 Typical Aircraft Dimensions

2.2. **Powerplant** – The aircraft is equipped with a Honeywell TPE331-10 turboprop engine with 900 SHP. It is mounted at the rear of the fuselage and drives a three-bladed variable-pitch pusher propeller. The TPE331 engine family has accumulated over 100 million hours on several different aircraft models.

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2.3. **Data Links** – The MQ-9 system provides continuous command and control communications from the GCS to the aircraft via LOS and/or SatCom. These

links allow real-time dynamic vehicle control and command updates by the pilot and also provide continuous monitoring of the health and status of the aircraft.

2.4. **Navigation** – The Ikhana aircraft navigation system differs from a "standard" MQ-9. The Ikhana navigation system is comprised of a single coupled EGI GPS/INS (Honeywell H764), three independent GPS boards (Novatel OEM4-G2), and three independent INS units (Honeywell HG1700). Each of the 3 GPS units is paired up with an independent INS unit to feed navigation data into one of three Flight Control computers. The 3 computers share the 4 sources of NAV data (1:EGI, 3:GPS), which includes "quality indices" (assumed to be FOM, or similar), and the nav data with the highest quality is selected (voted) for flying the aircraft.

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2.5. **Lighting** – The Ikhana aircraft is equipped with standard aircraft position lights and anti-collision strobe lights. All external lighting can be controlled by the pilot from the GCS.

2.6. **IFF Transponder** – The Ikhana aircraft is equipped with a Raytheon APX-119 IFF Digital Transponder (TSO Certified to TSO-C112). It has Mode 3/A and 3C capability. Although the APX-119 hardware has Mode S capability, the GCS/aircraft software does not currently (Feb 2007) have the ability to utilize Mode S. The pilot can change the transponder codes in-flight and command the transponder to "ident". The pilot can select code 7700 in the event of an appropriate aircraft emergency situation. In addition, in the event of a command and control data link loss ("lost link" event), the aircraft can be programmed to automatically retune to any transponder code, including 7600.

2.7. **GCS Situational Displays** – In the GCS, there are 3 basic types of displays available to the pilot in the GCS. The first type is a navigational map ("tracker display") that shows real-time aircraft position (from downlink telemetry). The pilot can select any of several maps for this display. The second type is the "heads-up display" (HUD) that shows real-time aircraft telemetry (rate of climb, altitude, heading, etc) displayed over a pilot selected camera view on the aircraft. The third type is system/subsystem monitoring displays. These displays can be selected by flight crew members to show digital and/or chart recorder style aircraft information to investigate potential aircraft anomalies in-flight.

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2.8. **Cameras –** The aircraft has two fixed forward looking cameras that are used by the pilot in the GCS HUD to maintain situational awareness. In the "as delivered" configuration, these 2 cameras are daylight cameras (essentially standard color cameras). NASA DFRC is procuring an infra-red (IR) forward looking camera to install into the aircraft for the 2007 WSFM. When installed, the pilot will have the choice of displaying a standard color, or IR camera display in the GCS HUD. Reference attachment: NASA 2007 Fire Mission - NAS Operational Capability for Detection of Other Aircraft Attachment.

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2.9. **Aircraft Data Recording Capability** – The aircraft has no standard on-board data recording capability. Science payloads added to the aircraft may have science data recording capability.

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3. Method of Pilotage

3.1. **Pilot Control** – The Ikhana aircraft is designed to be always under one of two types of control. Either the aircraft can be under the direct control of the pilot, or it can be under 1 of 2 type of preprogrammed autonomous control. The pilot can choose to define and uplink preprogrammed missions to the aircraft depending on the requirements of the planned flight.

3.1.1. **Pilot Direct Control** – For Ikhana operations, the aircraft is planned to be under direct pilot control for all missions at all times. The pilot uses several features of the MQ-9 system to implement direct control of the aircraft. The pilot can select any of the following types of direct control at any time during a typical Ikhana mission.

3.1.1.1. **Standard aircraft controls** – The pilot has full and direct control of all aircraft controls. The pilot generally uses this mode at <2000 ft AGL.

3.1.1.2. **Autopilot functions** – The pilot maintains direct control of all aircraft controls, but uses several "aircraft hold modes" that mimic the operation of manned aircraft autopilot functions (heading hold, altitude hold, etc). The pilot can engage any or all of these hold modes to reduce workload. The pilot generally uses this mode at >2000 ft AGL. The pilot has direct control of the aircraft when using these functions, and can disengage them at will.

3.1.1.3. **Preprogrammed Mission** – The pilot maintains direct control of all aircraft controls, but uses the MQ-9 capability to accept preprogrammed mission profiles from the pilot in a similar fashion as manned aircraft autopilots. In these cases, the pilot defines a mission profile and commands the aircraft to execute that profile. The pilot then monitors performance of the aircraft along that mission profile. At any time, the pilot has the capability to interrupt the preprogrammed mission and revert back to either of the other 2 types of direct aircraft control.

3.1.2. **Autonomous Aircraft Control** – The MQ-9 aircraft can be preprogrammed by the pilot to fly autonomously using on-board computers with no direct real-time pilot command and control of the aircraft. Although the Ikhana aircraft has the capability to perform both types of Autonomous missions, for the 2007 Western States Fire Mission, only the autonomous "lost link" mission type will be used. Although the pilot will be updating

and maintaining the lost link mission, this mode is a backup mode that is not expected to take control of the aircraft.

3.1.2.1. **Preprogrammed Autonomous Lost Link Mission** – The MQ-9 has the capability to fly a preprogrammed set of waypoints and actions in the event that it loses all command and control inputs from the GCS/pilot. This is generally referred to as the "lost link" mission. The "actions" include autonomous changes to transponder codes (such as 7600), altitudes, airspeed, etc. This backup mode is designed to ensure that the aircraft performs a predictable mission profile in the event of lost link. For a typical mission, the pilot inputs an appropriate lost link mission prior to the flight. During the flight, the pilot updates the "entry point" into the lost link mission. The pilot has the full capability to delete, update, and modify the lost link mission during a flight. The mission is designed provide a predictable return to base (RTB) function to the aircraft. At the end of the lost link mission, it is anticipated that the GCS LOS command and control system would be able to take control of the aircraft for landing. At the end of the lost link mission, if the GCS LOS command and control system is not able to take control of the aircraft, the aircraft will eventually run out of fuel and contact the ground in a predetermined and preprogrammed area. The predetermined and preprogrammed area is specifically selected by DFRC Range Safety to protect the public from danger in this scenario. For the 2007 WSFM, this predetermined and preprogrammed area is within the R-2508 SUA complex.

3.1.2.2. **Preprogrammed Autonomous Mission** – This type of mission is a variation of the directly controlled preprogrammed mission. The preprogrammed mission has an attribute that can designate legs or waypoints to be "lost link OK". Using this attribute, the pilot can define a preprogrammed mission (or portion of a mission) that will executed, even if the aircraft loses the command and control link from the GCS. This capability will not be utilized during the 2007 Western States Fire Mission.

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