Executive Summary

AR3P Program Background (2017-2019) and Robotic Hot Refueling Demonstrations (Sep-Oct 2020)

Updated
4 November 2020

The **Autonomous & Robotic Remote Refuel Point (AR3P)** is a science & technology (S&T) program previously executed by the Army Futures Command (AFC) CCDC Aviation & Missile Center (AvMC.) Funding sources include the OSD Coalition Warfare Program (US-UK), OSD Operational Energy Capability Improvement Fund (OECIF), DoD Rapid Innovation Fund (RIF), and Small Business Innovation Research.

The AFC Sustainment Battle Lab featured the AR3P during the **Maneuver Support, Sustainment, and Protection Integration Exercise (MSSPIX)** at Fort Pickett VA on Sep 16, 2020. The concept demonstration focused on autonomous refueling of a tactical helicopter in an operational scenario, and represented an "art of the possible" prototype capability to potentially inform requirements developers. There is currently not a validated requirement for such capability in the Army. The AR3P was presented as a Concept Development Prototype (CDP) which was Technology Readiness Level 5 at entry to the MSSPIX event, and met criteria for designation as **TRL 6** upon exit. However, the **Army is now in the process of divesting the S&T program and its Technical Data Package**; other Services may be interested.

At MSSPIX, contractors supporting the **AvMC Energy Lab** operated the AR3P system. **Kaman Aerospace** operated the USMC K-MAX aircraft which was refueled. **NAVAIR** / PMA-266 provided the Interim Flight Clearance (IFC) for flight of the K-MAX with the modified fuel port. The **244th Expeditionary Combat Aviation Brigade (US Army Reserve)** provided the CH-47F and crew. The **Virginia Army National Guard (VAARNG)** provided the slingload riggers, Palletized Loading System (PLS), surrogate conex container, and "wingman" UH-60L aircraft and crew. **Multiple successful iterations of K-MAX "hot refueling"** (engine and rotors turning) were performed with no anomalies, suggesting a "NASCAR pit crew-like" capability.

- Reduces Soldier exposure
- Aircraft agnostic design – four platforms demonstrated to date
- "Hot" refuel capable, refuel demonstrated on running K-MAX
- Survivability & (C2) concepts
- Hybrid power system – 4 x 6T batteries for 96 hours' silent operations
- Ruggedized transportability; internal transport support
- Autonomous grounding
- Supports fuel demand reduction

Historical demonstrations (see figures on following page):

- **TRL 4 demo 2017**: AH-64 hulk, initial lab demo, two robots, passed water to two fuel ports
- **TRL 5 demo 2019**: UH-60L (Fully Mission Capable (FMC) aircraft), AR3P Concept Demonstration Prototype (CDP) configuration, robotic engagements with aircraft not running, did not pass fuel
- **TRL 5 demo 2019**: Mosquito rotary-wing UAV, AR3P CDP engagements, aircraft vibration
- **TRL 6 demo Sep 2020**: USMC K-MAX aircraft (piloted), flew-in, remained running during AR3P CDP engagement and actual passing of JP-8 ("hot refuel")
- **TRL 6 demo, Oct 2020:** commercial S-70 (Black Hawk) hot engagement

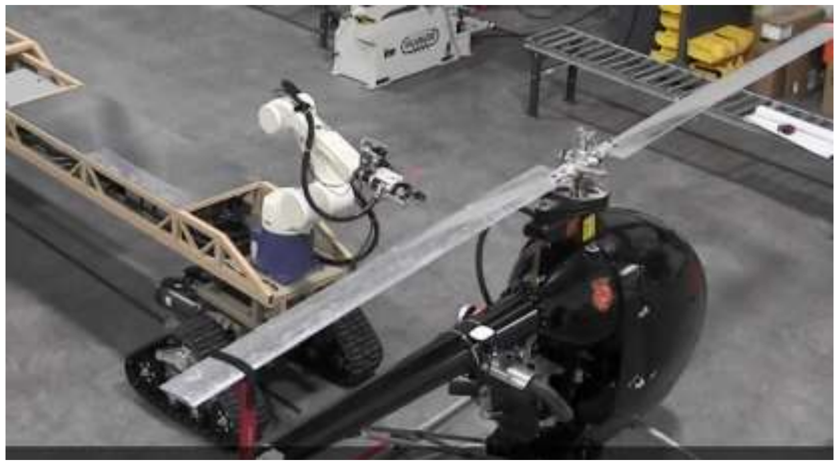

Figure 2. 2019, TRL 5 AR3P CDP Configuration, Mosquito UAV, vibratory engagements, approach from side, no fuel/water passage

Figure 3. 2019, TRL 5 AR3P CDP Configuration, UH-60L, dry engagements (engine/rotors static), approach from side, passed fuel to the aircraft

September 3-16, 2020. Maneuver Support, Sustainment, and Protection Integration Exercise (MSSPIX), Fort Pickett, VA, hosted by the AFC Sustainment Battle Lab. The operational vignette demonstrated two methods of emplacement of the containerized AR3P Concept Demonstration Prototype (CDP): Palletized Loading System (PLS) of the actual AR3P container, and CH-47F slingload of a surrogate replica conex container of same size/weight.

Figure 4. Emplacement modes demonstrated for AR3P (via PLS) and AR3P conex replica (via CH-47F)

(cont.) September 3-16, 2020. Maneuver Support, Sustainment, and Protection Integration Exercise (MSSPIX.) Following emplacement of the containerized AR3P, a two-ship flight of UH-60L (lead) and K-MAX (wingman) arrived into the LZ area. The UH-60L broke off to assume a notional aerial security role. The K-MAX hover-taxied and ground-taxied into position for a front approach by the AR3P robot. The rotor tilt and height precluded a robotic approach from the side. The LIDAR, robotic vision system, and movement of the extension rail and robotic arm articulation functioned nominally in all test events and demonstration with this approach-from-the-front. The video below is from Sep 9, 2020, which was the first end-to-end test hot refueling; the Sep 16 VIP demonstration progressed similarly.

Video (**unlisted YouTube video**): https://youtu.be/GJz3FbsH2Iw.

Figure 5. K-MAX Hot Refueling Sequence

Hot Refueling Demonstration, S-70 (commercial variant of UH-60A), Oct 12, 2020. The AR3P engineering team conducted a hot refueling demonstration of the S-70 helicopter at a contractor facility in Tullahoma, TN. The S-70 is the commercial variant of a UH-60A. As had been recommended via a safety of flight review board (SOFRB) supporting the UH-60L engagement test in Nov 2019, the robotic system approached the S-70 from the left side, which offered adequate clearance of the rotating tip path plane.

Video (**unlisted Vimeo link**): https://vimeo.com/467950954/516ad438e0

Figure 6. S-70 Hot Refueling sequence

S-70 approach, landing, ground taxi, and park
(precision tolerance +/- 3 feet, +/- 10 deg)

AR3P extension rail approach, robotic arm engagement, simulated refueling.
ROTORS TURNING

Arm retraction, rail retraction, and aircraft departure.
HOT ENGAGEMENT COMPLETE

The AR3P *Concept Demonstration Prototype* (CDP) which was featured at MSSPIX ’20 utilized several **safety controls** that are progressively being proven unnecessary, and will not be necessary in the follow-on prototype design. Those controls included the following:

- A **hard-wire communication line** between a control trailer and the AR3P container enabled the engineering team to monitor status and provide a safety shutoff capability.
- The robotics engineers tuned their software to **step-down the movement speed** of both the extension rail and the articulated robotic arm movement. Again, these were safety mitigations given the “first” of refueling a rotors-turning aircraft, which tested and retested in the days prior to the VIP demonstration on September 16.
- Finally, despite the verifiable automatic grounding capability inside the AR3P container, and the failsafe-designed electrostatic discharge function on the robotic arm “end effector,” a soldier attached a **wired grounding cable** to the K-MAX just prior to refueling.
- While not a safety measure, the **CDP fuel tank capacity** was only 90 gallons, enough for a safe concept demonstration, but not relevant for an operational design. The objective capacity would be approximately 1200 gallons for a sling-loadable configuration.

The envisioned follow-on ***Objective Fielding Prototype*** **(OFP)** design provides true remote command and control (C2) from a joint operations center via SATCOM, as well as provisions to integrate system health & status reporting, and threat awareness via layered surveillance and security functions (e.g. satellite imaging, MALE UAS, tethered UAS, on-board panoramic IR surveillance.) Many of these security & C2 concepts were developed by the **UK Defence Science & Technology Lab (DSTL)** as an extension to their program for *Sensing for Asset Protection with Integrated Electronic Networked Technology* (SAPIENT.) This work was partially funded under the **OSD Coalition Warfare Program** and executed under the US-UK Project Agreement for “Total Survivability for Advanced Rotary Wing Aircraft.”

Consideration will next be given to further ruggedizing the system to include an investigation into **C-17 airdrop emplacement**, integration of the robotic system onto **Navy logistics barges** for fueling aircraft, and reconfiguring to support **fueling of ground vehicle platforms**. These integrations will likely not have the same restrictions on weight, containerization, and fuel capacity of the AR3P CDP design.

Envisioned in the variety of configurations (e.g. containerized, barge-deployed, ground system support, aviation system support), the core AR3P capability will support **Joint All Domain Operations (JADO)** and the Army’s Multi-Domain Operations (MDO.) The innovative technology of AR3P could significantly extend the mission endurance and range of Army and joint aviation and ground vehicle assets, provide greater mission flexibility, while reducing the threat exposure of ground support soldiers.

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