Degraded Visual Environment Mitigation (DVE-M) Program, Yuma 2016 Flight Trial

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Approved for Public Release AMRDEC 2615
April 4, 2017 Oslo Norway;   April 6, 2017 Braunschweig Germany;
April 24, 2017 Ft. Rucker Alabama USA

Outline

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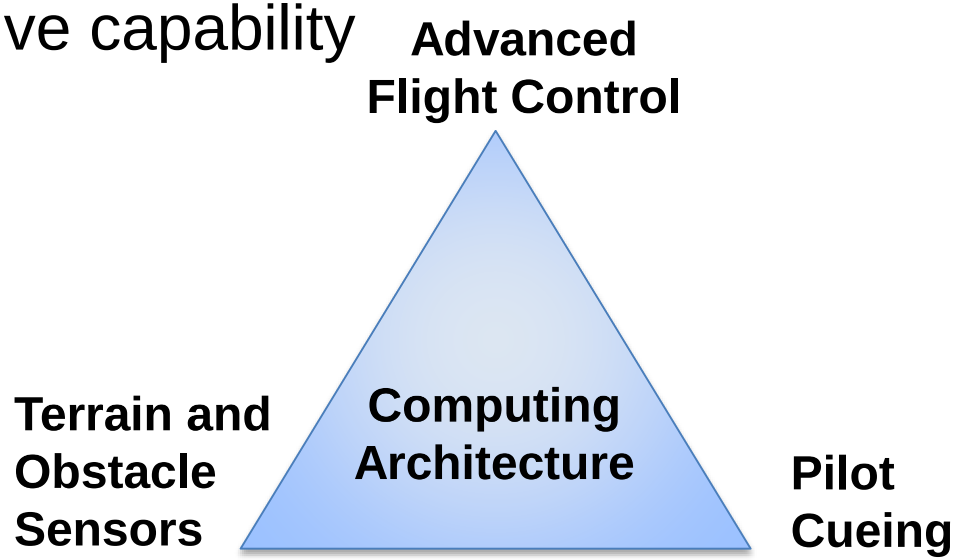
- Conclusions
- European Trials Videos

Introduction

Purpose

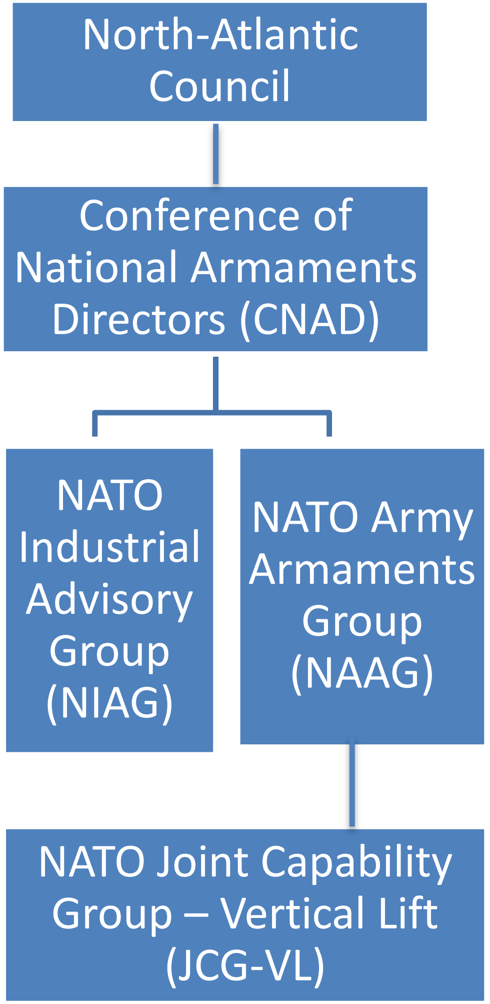
The purpose of the Degraded Visual Environment Mitigation (DVE-M) program is to generate knowledge about technical solutions and procedures that enable operations in degraded visual environments.

- Decrease the number of accidents.
- Enable intentional operations in DVE when the adversary cannot operate – a disruptive capability



NATO Sponsorship

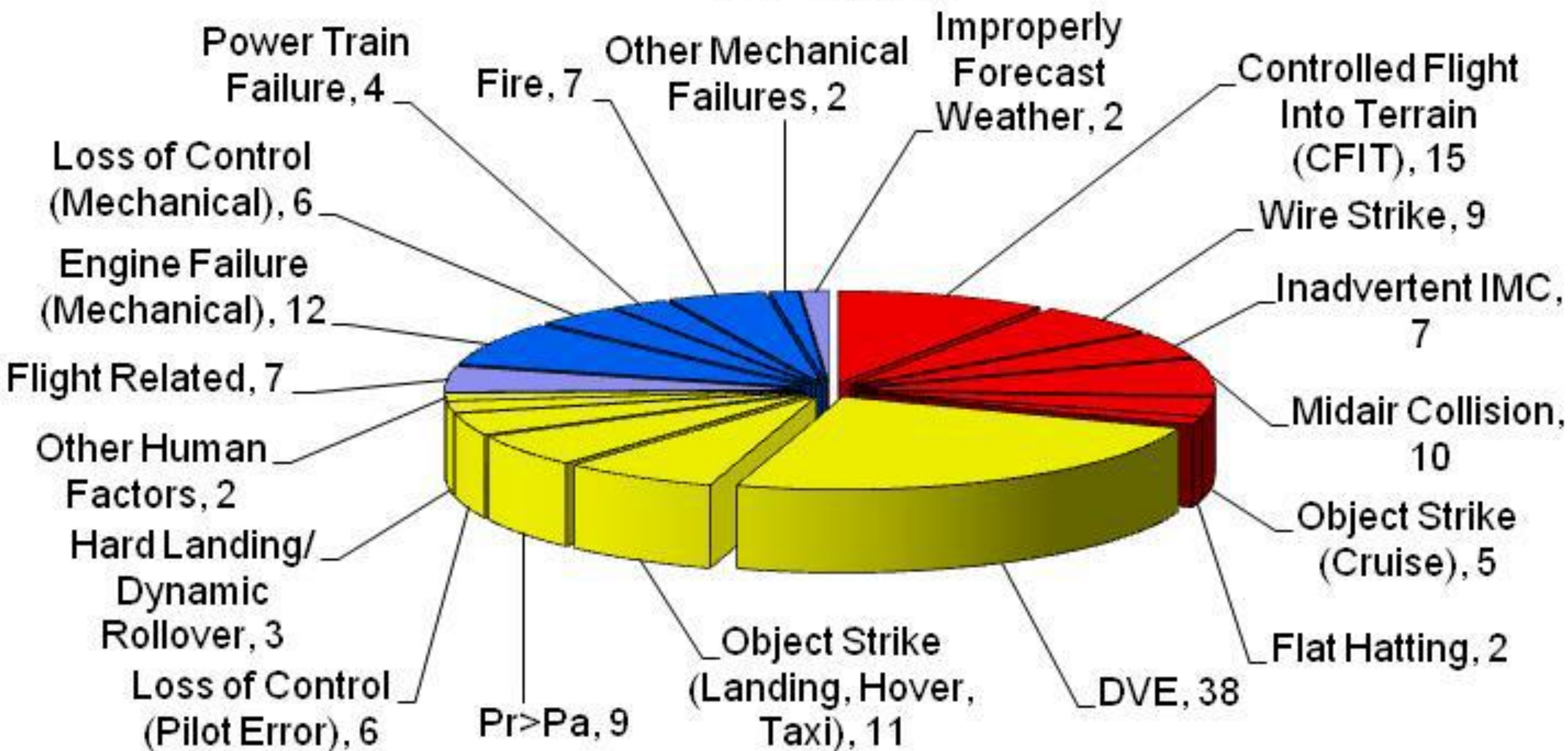
- NATO Joint Capability Group-Vertical Lift (JCG-VL) is the NATO Flight Trials Sponsor for the 2016 Yuma Flight Trials and the 2017 Europe Flight Trials.
- A DVE Informal Working Group (IWG) was established by NATO JCG-VL in September 2014 to lead the planning of the flight trials.
- DVE IWG Mission:
  - Primary: To plan and conduct the Europe Rotorcraft DVE Flight Trials to take place in Germany and Switzerland in FEB 2017.
  - Secondary: To assist the US RDECOM DVE Mitigation Program in the planning of the Rotorcraft DVE Flight Trials to take place in Yuma, Arizona in SEP 2016.



NATO Participation at Yuma

System Participant	Platform Type	Configuration
US Army RDECOM DVE-M	EH-60L #657 (ADD-AFDD, Moffett Field, CA based)	• Modernized Control Laws (MCLAWS) • Integrated Cueing Environment (ICE) • Two Sensor Lines of Effort (LOE) - LOE 1: SNC Radar, LIDAR & FLIR, DTED - LOE 2: Areté, LIDAR & FLIR, DTED
Airbus	Mi-2 from U. of Iowa Operator Perf. Lab (OPL)	Airbus DS SFERION system • HMD and PMD • LADAR and DTED
CDRDC (Defence Research & Development Canada)	Ground Only (tower)	Ladar characterization
United Kingdom Defence Science and Technology Laboratory	Ground Only (tower)	IR characterization

Number of U.S. Combat, Non-Hostile, Rotorcraft Losses for OEF/OIF (Oct 2001 – Sep 2009)



157 Total. Hostile Action Losses = 70.
Graph from Couch and Lindell, 2010.
OEF = Operation Enduring Freedom
OIF = Operation Iraqi Freedom

Yellow: Low speed / hover, human factors
Red: High speed, human factors
Blue: Mechanical, non-human factors
Violet: Weather forecast and Undetermined

Degraded Visual Environments at Yuma

Aircraft Induced DVE

Brownout

Whiteout

Yuma Trials

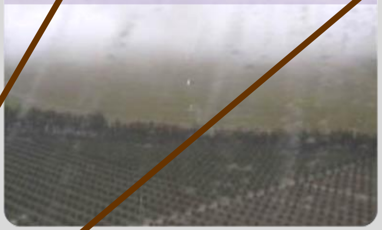
Aircraft Independent Degraded Visual Environments

Smoke

Sand / Dust

Fog

Rain



Clouds

Snow

Smog

Night

Flat Light

Use weather to your military advantage

Research Systems Description

Research Systems Overview

Integrated DVE Systems

- Multi-Spectral Terrain/Obstacle Sensors
- Programmable Research Flight Control System
- Programmable Integrated Cueing Environment (ICE) System

Instrumentation

- EGI, GPS
- Video Combiners and Recorders
- Data Acquisition Sensors and Recorders

Multi-Spectral Terrain / Obstacle Sensors

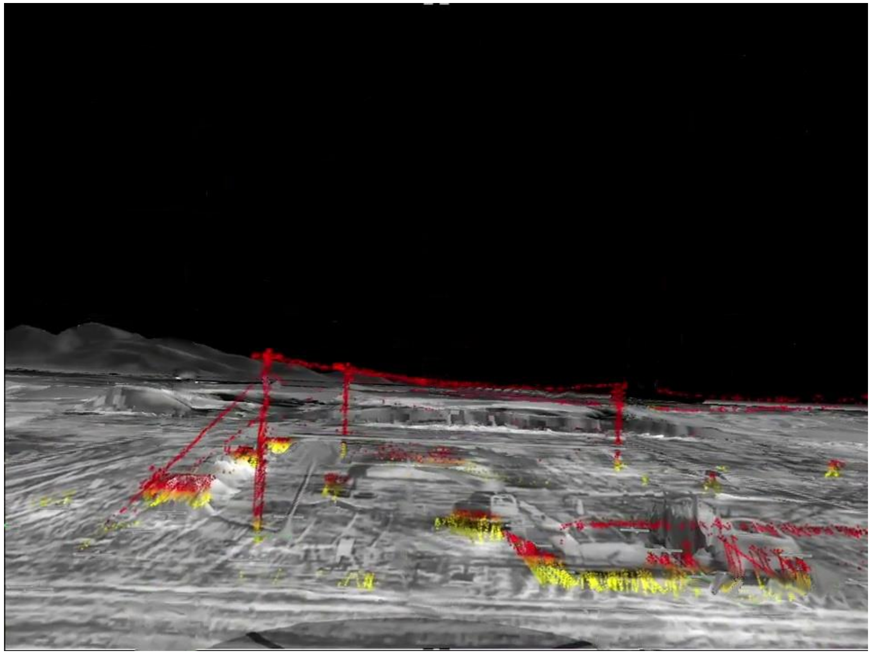
Sierra Nevada Corp

- RADAR (3D)
- LADAR (3D)
- Infrared (2D)
- Pre-Stored Terrain (3D)

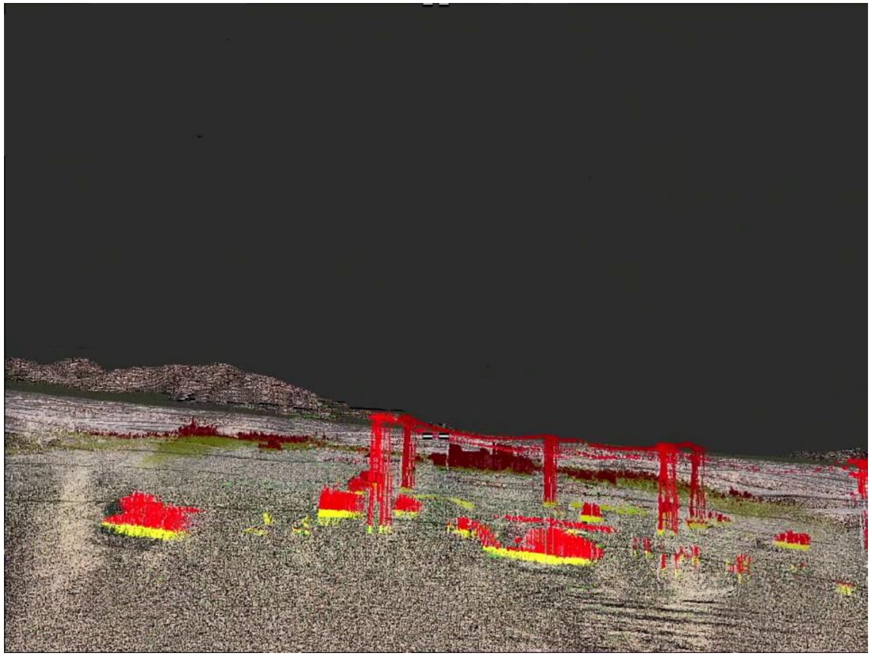
Areté Associates

- LADAR (3D)
- Infrared (2D)
- Pre-Stored Terrain (3D)

Fused Sensor and DTED Imagery



Sierra Nevada Corp

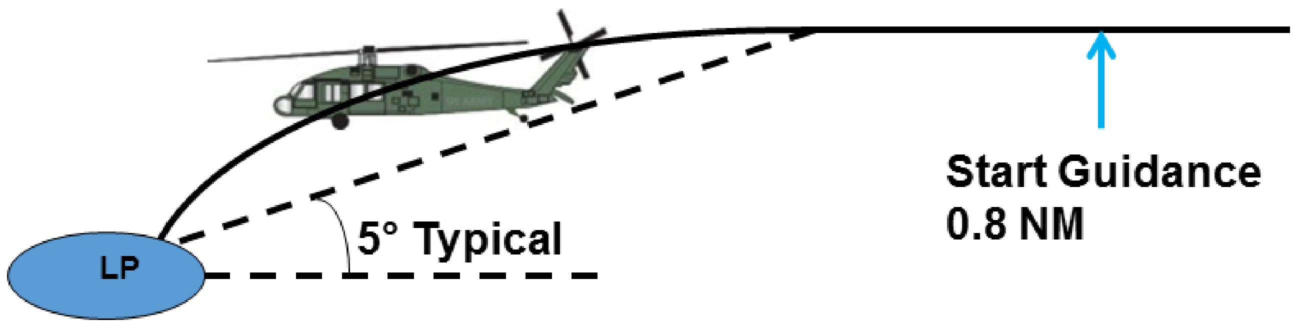


Areté Associates

Sensors provide data to the fusion processor for a 3D, persistent database of elevations

- Used by the guidance algorithms for symbology and coll. coupling
- Used by the graphics generator to render the pilot's displays

Guidance for the Approach to Landing Maneuver



Guidance profile is close to a clear day approach to landing.

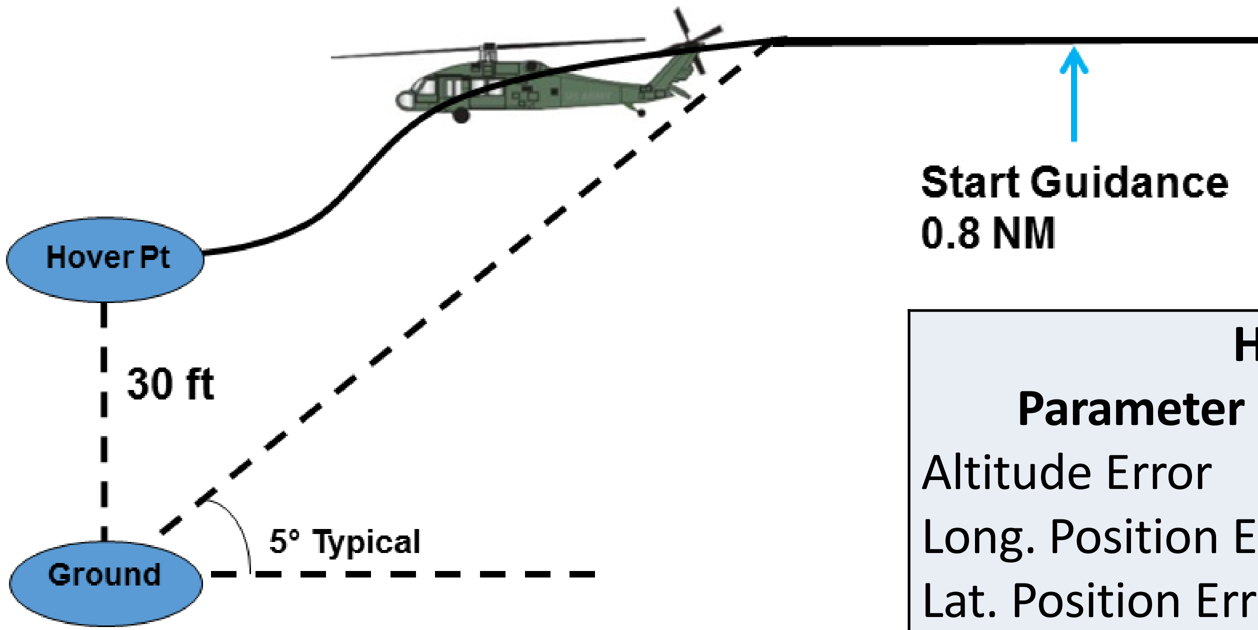
Mode A:
Guidance can use 3D sensor database of terrain and obstacle elevations.

Or

Mode B:
Guidance can use pre-loaded obstacle location and height data and radar altimeter.

Landing Criteria		
Parameter	**Desired**	**Adequate**
Vertical Speed	< 150 ft/min	< 300 ft/min
Forward Speed	< 2 kts	< 5 kts
Aft Speed	= 0 kts	< 0.5 kts
Lateral Speed	< 0.5 kts	< 1.0 kts
Long. Position	± 10 ft	± 20 ft
Lateral Position	± 6 ft	± 10 ft
Heading	± 5 deg	± 10 deg

Guidance for the Approach to Hover Maneuver



Hover Criteria

Parameter	Desired	Adequate
Altitude Error	± 3 ft	± 6 ft
Long. Position Error	± 3 ft	± 6 ft
Lat. Position Error	± 3 ft	± 6 ft
Heading	± 3 deg	± 6 deg

Flight Control Systems Available

Mode 1

Standard EH-60L

- **Cyclic (pitch and roll)**
  - SAS (10% authority)
  - Angular rate cmd.
  - No pos. hold modes
- **Pedals**
  - SAS
  - Heading hold
- **Collective**
  - No coupling
  - No hold modes

Mode 2

Research Flight Control System

- **Cyclic (pitch and roll)**
  - MCLAWS (10% authority)
  - Attitude cmd / attitude hold
  - Position hold modes
- **Pedals**
  - MCLAWS
  - Heading hold
- **Collective**
  - Coupled to guidance
  - Altitude hold mode

Flight Control Systems Available

Mode 3

Standard EH-60L

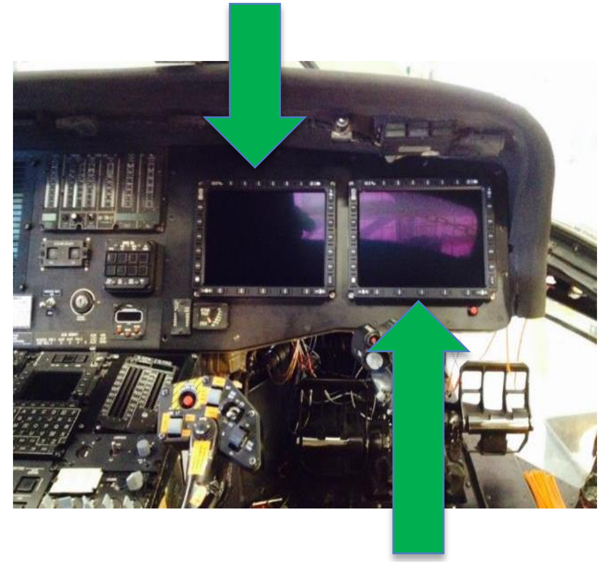
- **Cyclic (pitch and roll)**
  - SAS (10% authority)
  - Angular rate cmd.
  - No hold modes
- **Pedals**
  - SAS
  - Heading hold

Research Flight Control System

- **Collective**
  - Coupled to guidance
  - Altitude hold mode

Pilot Displays

Top down view of sensor data



Safety Pilot HMD
- Monochrome
- Non-Head Tracked
- 18x18 deg FOV
- VGA (640x480)

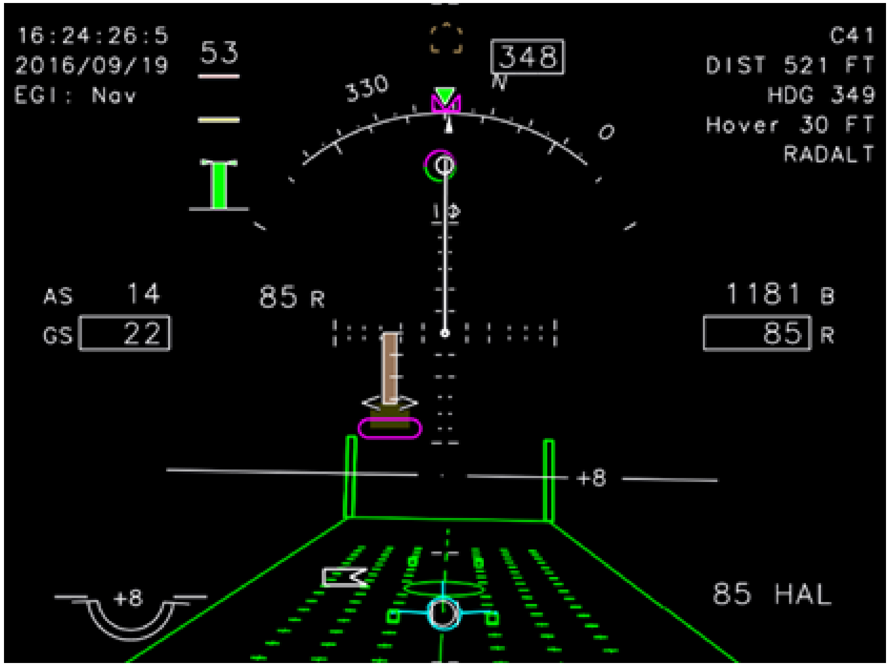
Safety Pilot PMD
- Color
- 8 inch diagonal
- 800x600 pixels

Evaluation Pilot Primary Flight Display
- Color
- 10 inch diagonal
- 1024x768 pixels

Two ICE Symbology Pages

Enroute Page

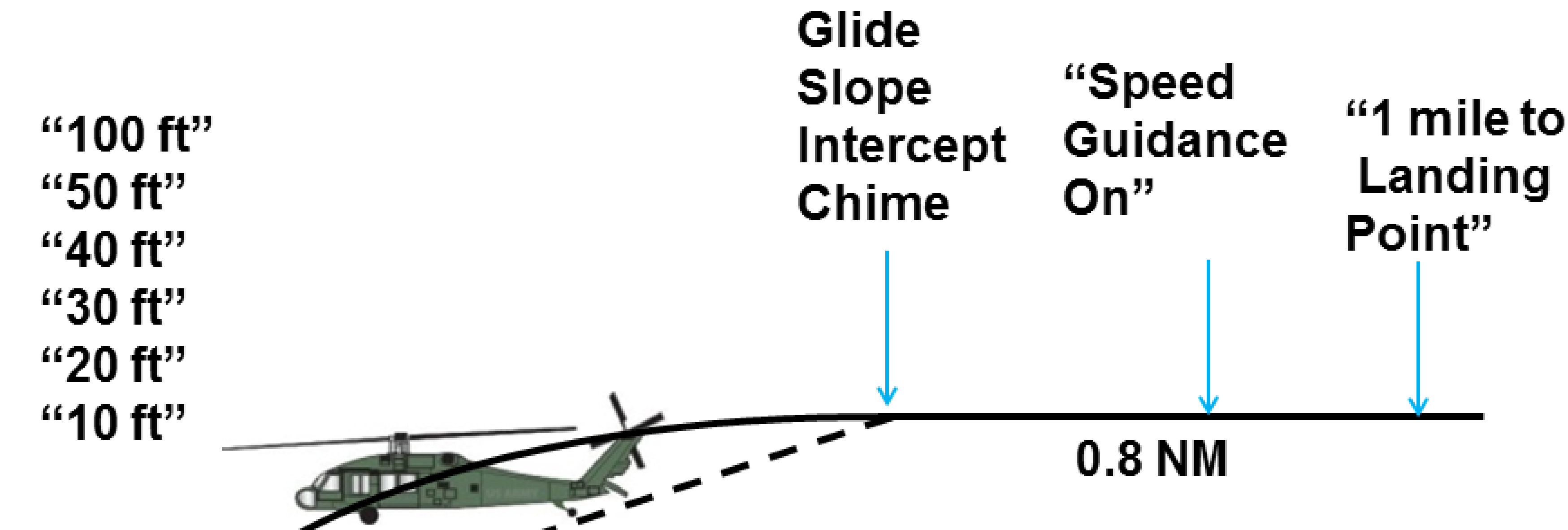
- Above 60 knots



Hover / Approach / Take-off (HAT) Page

- Below 60 knots
- Any speed when approach guidance is ON

Aural Cueing



Additional aural cues were implemented for flight control mode changes, and cautions and warnings for excessive torque and excessive vertical speed near the ground.

Tactile (Vibration) System

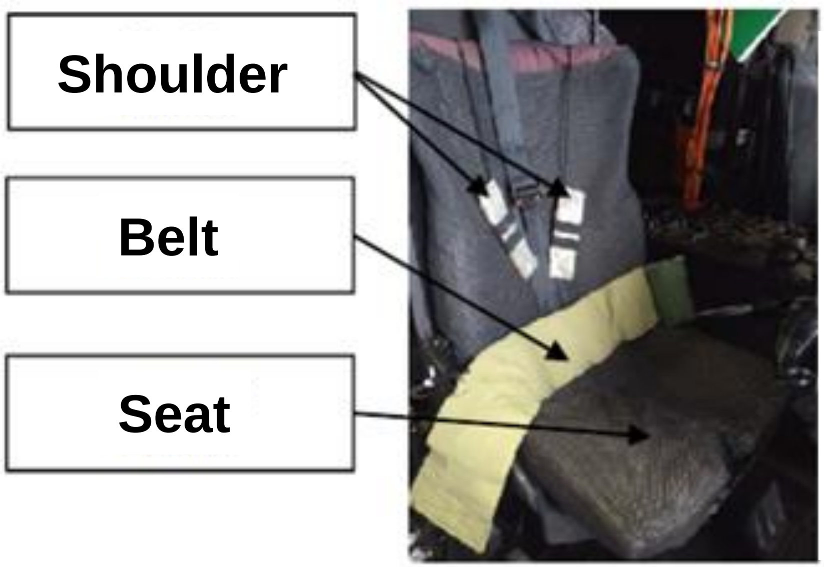
Modes:

- Approach to hover/landing
- Hover position keeping

Pilot should always move away from vibration

Categories:

- Advisory: 200ms of vibration repeated at 1 Hz
- Caution: 100ms of vibration repeated at 2 Hz
- Warning: 50ms of vibration repeated at 4 Hz



8 direction belt

Methods

Independent Variables

- For cyclic and pedals, MCLAWS vs. standard UH-60A/L (attitude command / attitude hold vs. rate command)
- Collective Coupling OFF vs. ON
- Aural Cueing OFF vs. ON
- Tactile Cueing OFF vs. ON

ICE visual cueing used for all maneuvers due to airworthiness requirements.

Independent Variables

- For cyclic and pedals, MCLAWS vs. standard UH-60A/L (attitude command / attitude hold vs. rate command)
- Collective Coupling OFF vs. ON
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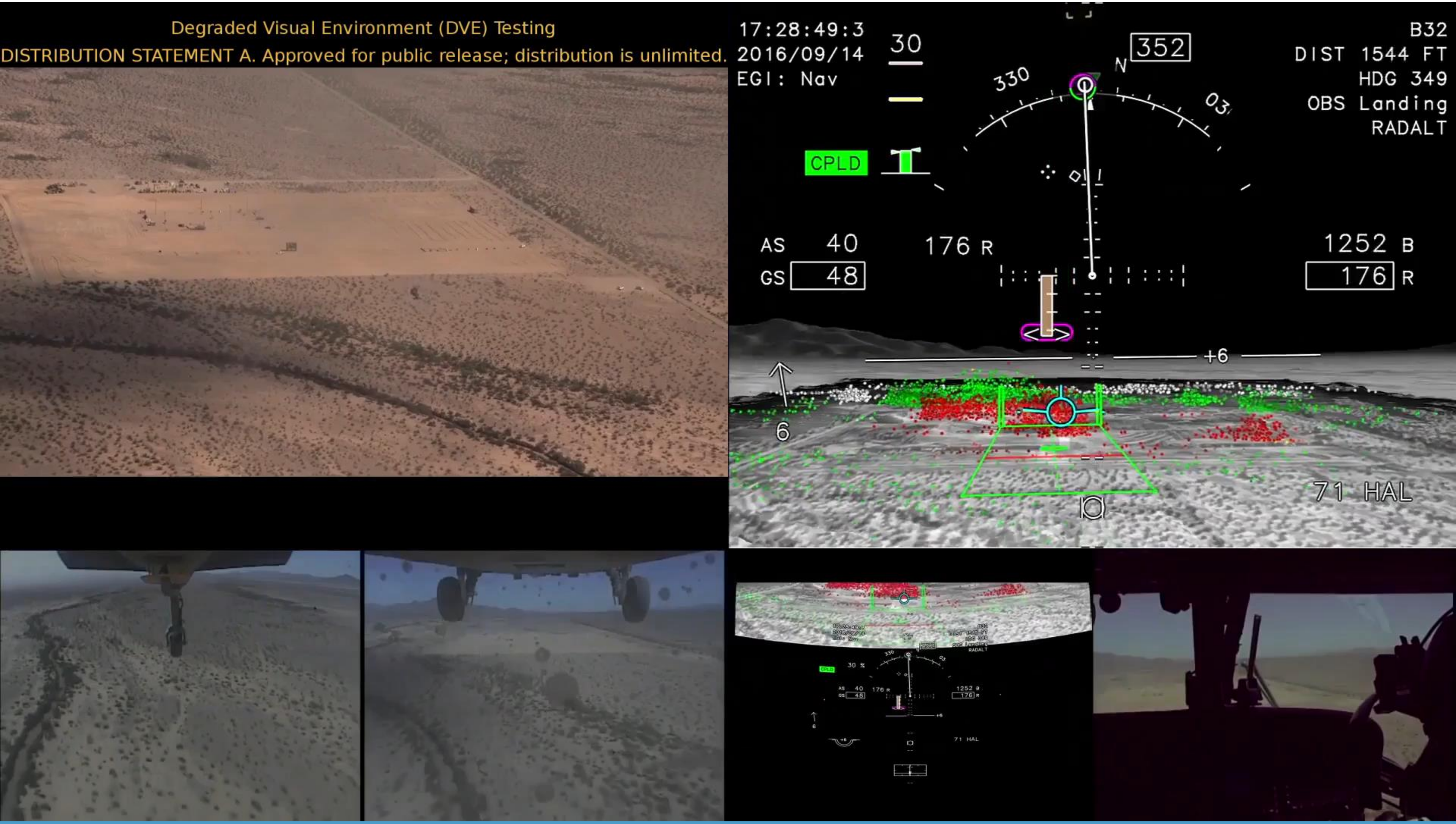
- Tactile Cueing OFF vs. ON

Focus of performance data discussion

ICE visual cueing used for all maneuvers due to airworthiness requirements.

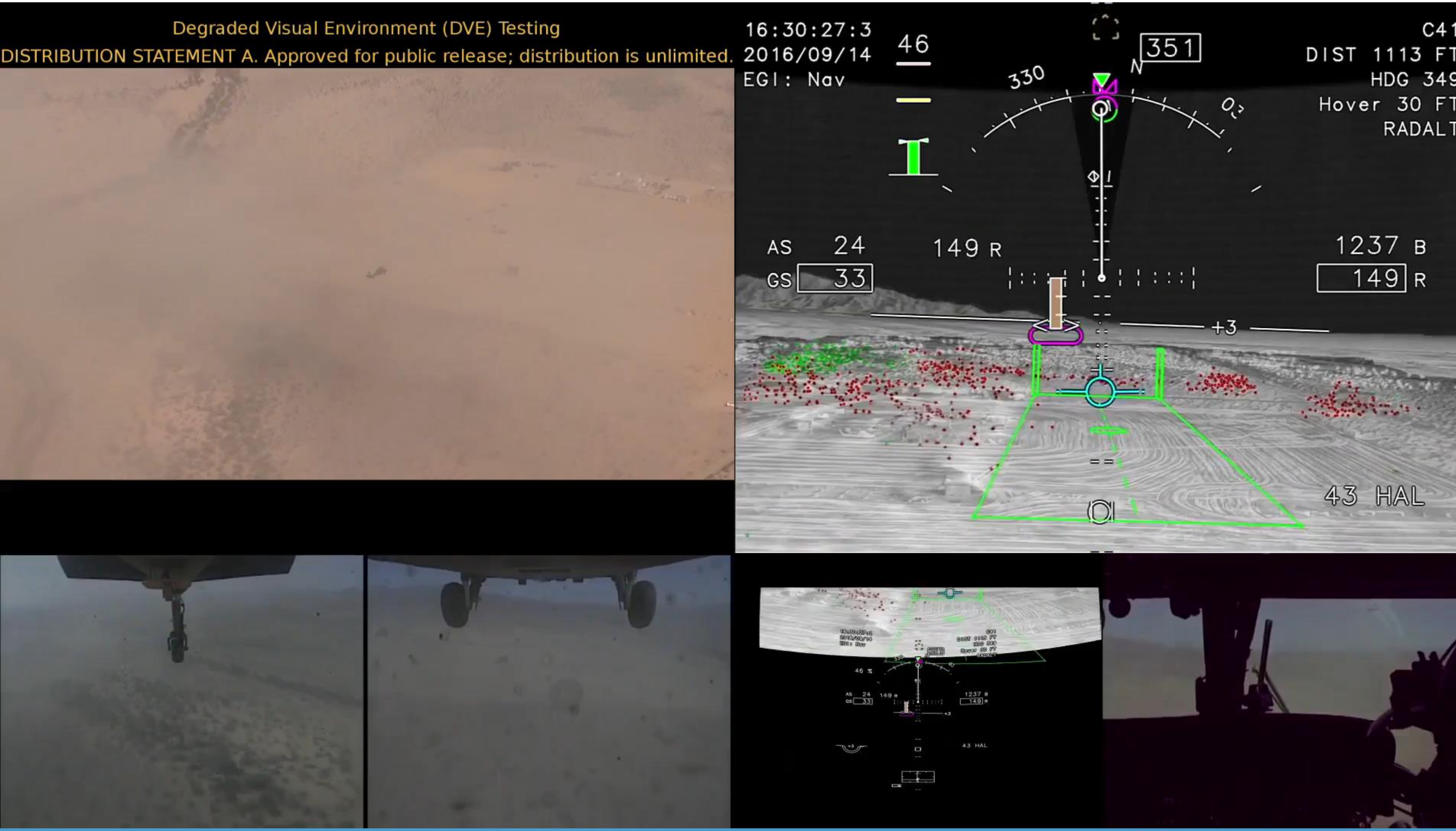
Results

Video of Landing in Yuma



Video of Landing in Yuma

Video of Hover in Yuma



Overall Test Statistics

- **14 Evaluation flights (29.3 flight hours)** conducted using four evaluation pilots
  - 6 Sorties (13.5 flight hours) with LOE 1 (engine replacement required)
  - 8 Sorties (15.8 flight hours) with LOE 2

- 152 record test points (approaches to landing or hover) were attempted
  - **76 Successful brownout landings** (including demonstration points)
  - **69 Successful extended (30 sec) brownout hovers** (including demonstration points)
  - **7 Approaches resulted in go-arounds** due to pilot performance (not meeting established maneuver standards for safety; due primarily to adverse winds and/or swirling dust effects)
  - These numbers do not include approaches abandoned due to system anomalies or sensor failures

- **Hover maneuvers totaled more than 34 cumulative minutes of brownout** at 30 ft AGL.

Landing Performance

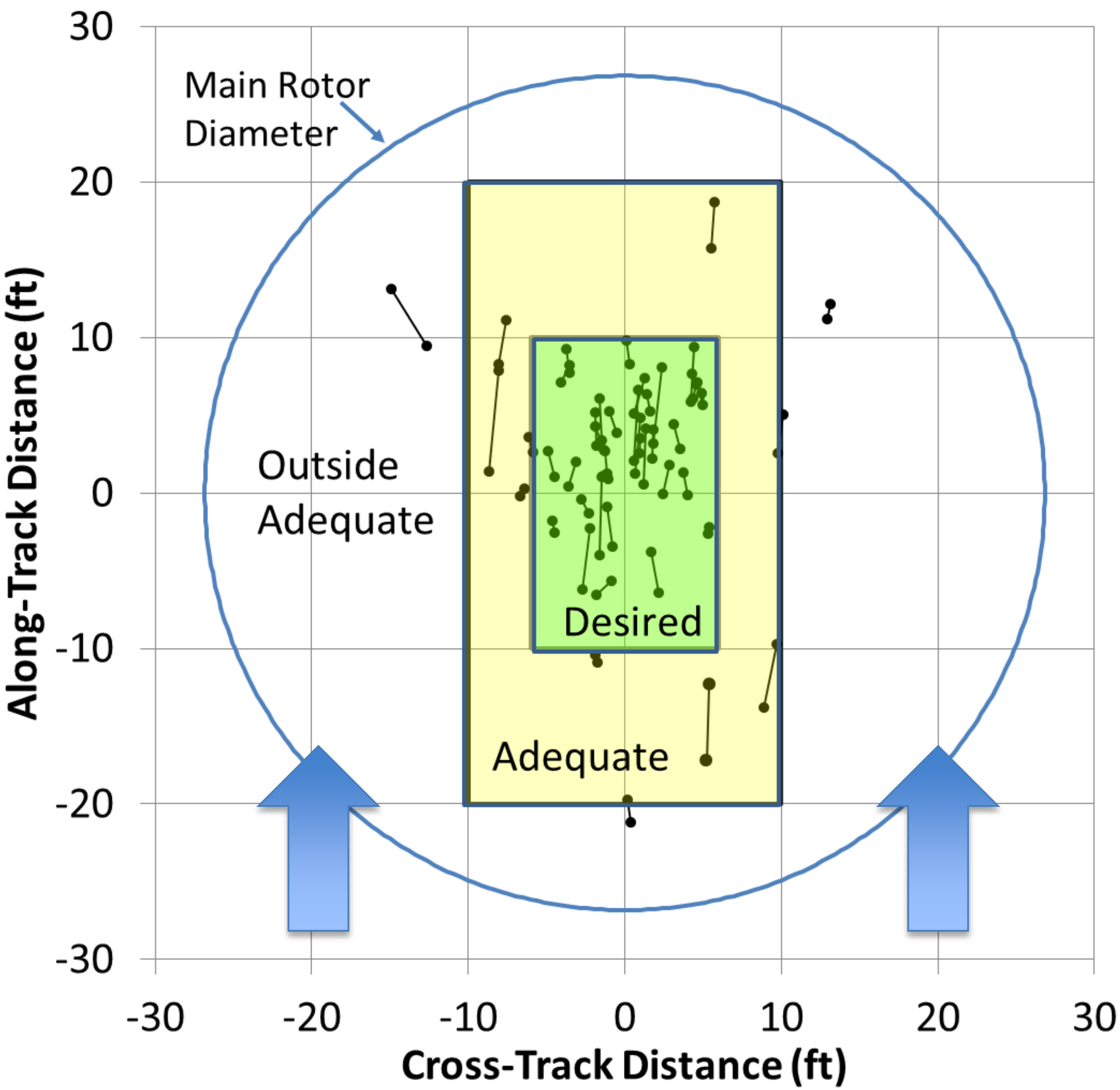
64 Landings (not including demonstration points)

- All touchdowns within 22 ft of intended landing point (mean 6 ft)
- All forward speeds within 4 knots (mean 1.5 knots)
- All lateral speeds ≤ 1.5 knots (mean 0.3 knots)
- All vertical speeds ≤ 180 ft/min (mean 97 ft/min)

6 Go-Arounds

(Distances as measured by the Embedded GPS/INS (EGI) inertial sensor)

Landing Positions



All 64 landings were within a main rotor diameter

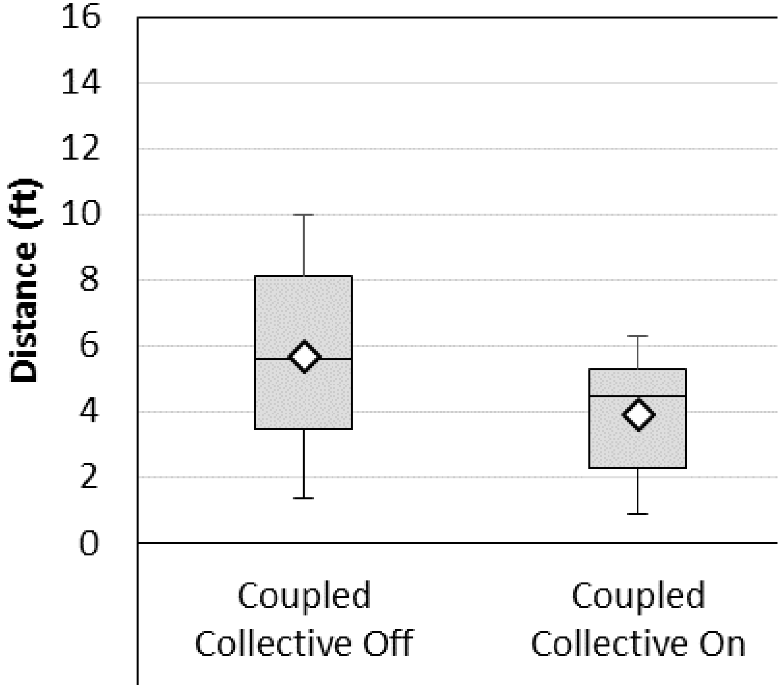
53% of landings met all 6 desired criteria.

92% of landings met at least the 6 adequate criteria.

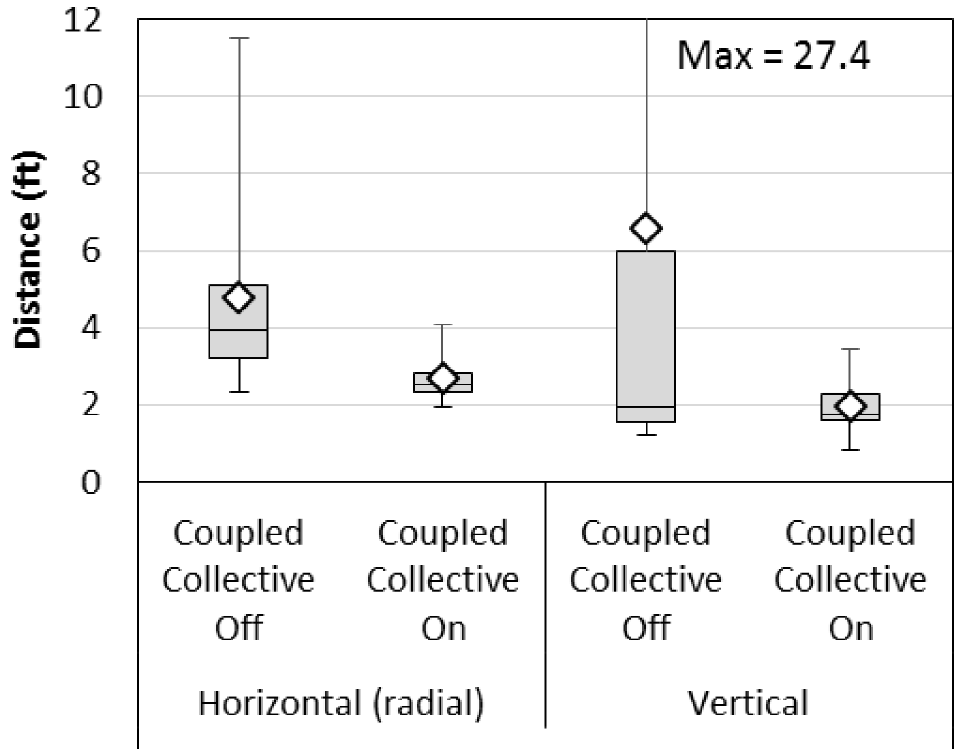
8% of landings had at least one parameter outside of adequate
- 1 short
- 2 wide
- 4 had lateral speed 1.0 - 1.5 knots

Performance

Touchdown Positon Error (Radial)
64 Landings



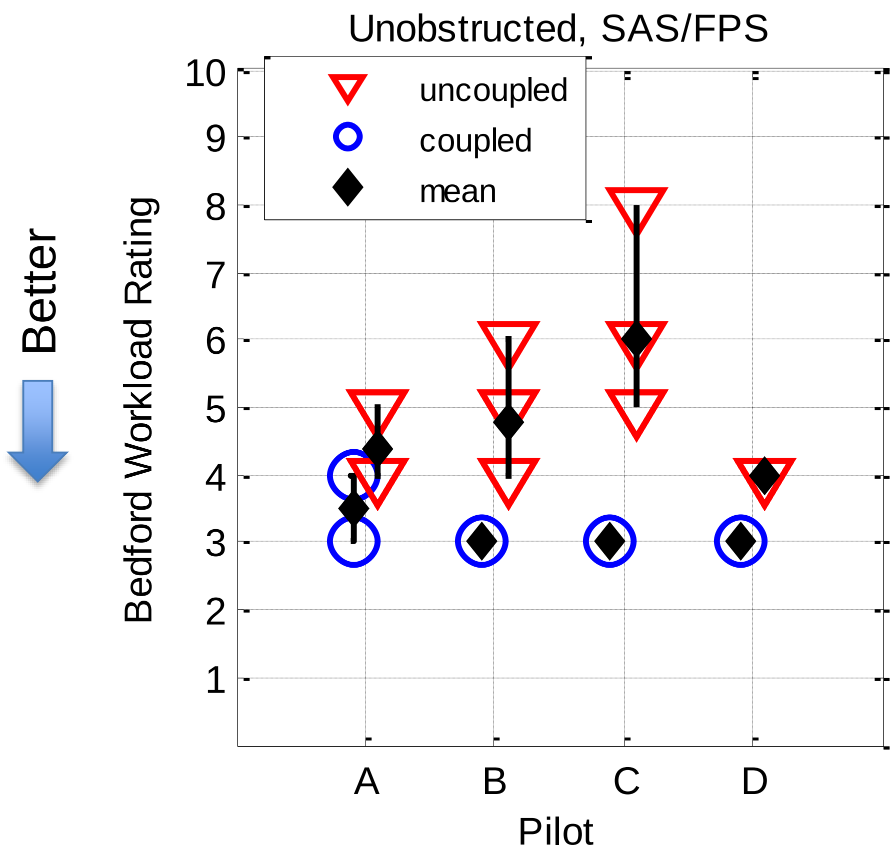
Hover Position RMS Error
55 Hovers

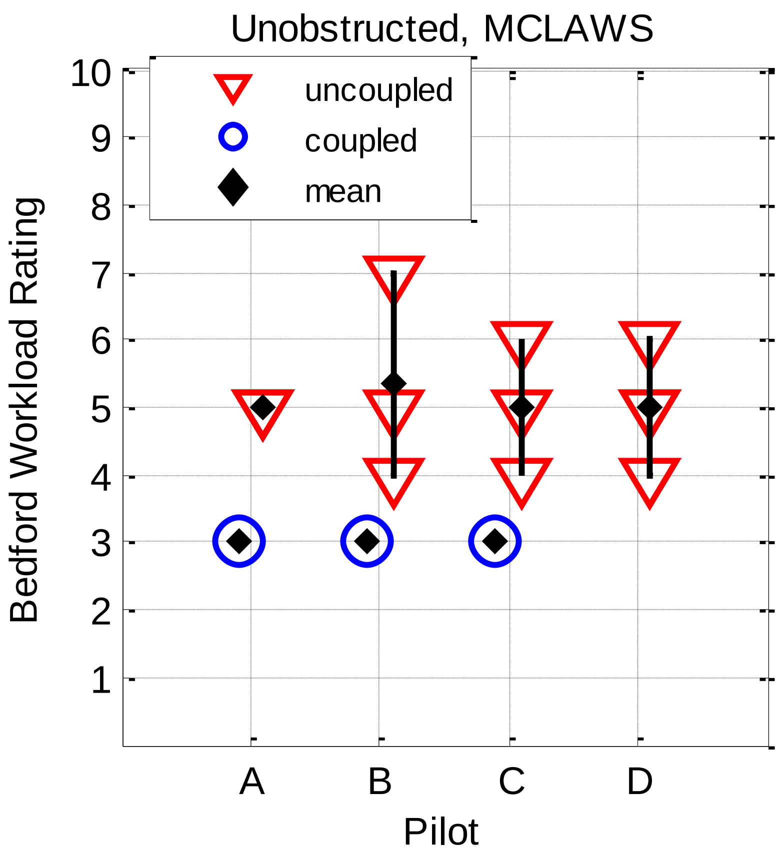


Landing Radial Error: $p = 0.03$
Hover Radial Error: $p = 0.06$
Vertical RMS Error: Not significant

Collective coupling enables more consistent hover performance.

Bedford Workload Rating for Unobstructed Landings

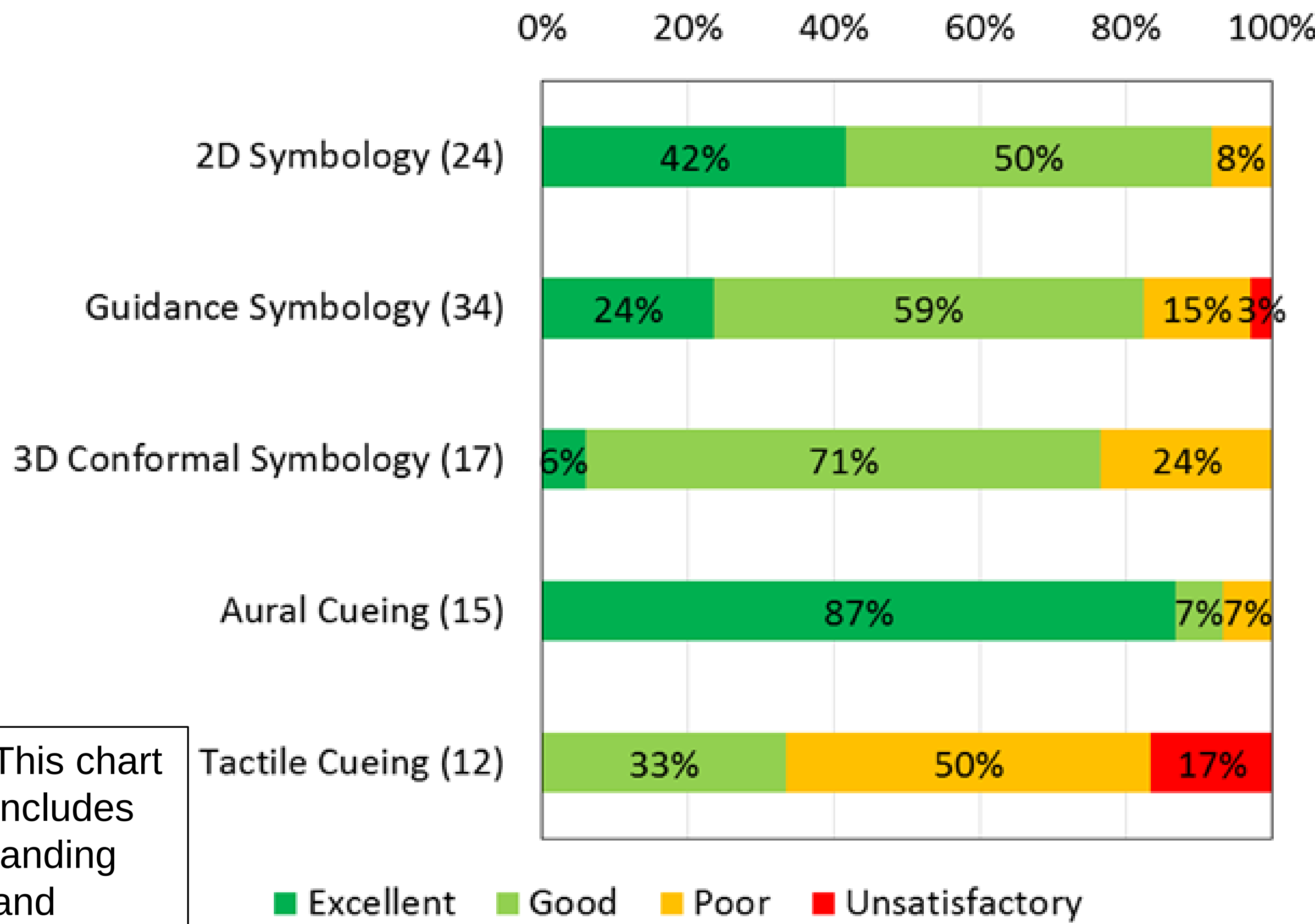




Collective coupling reduces workload for landing

Coupling refers to collective axis only

Summary Usability Ratings of ICE Components



This chart includes landing and hovers

Tactile was the only component mostly poorly rated

- Vib. in more than axis at a time.
- Thresholds too Sensitive.
- Need to turn off with acknowledge button or when converging to desired performance.

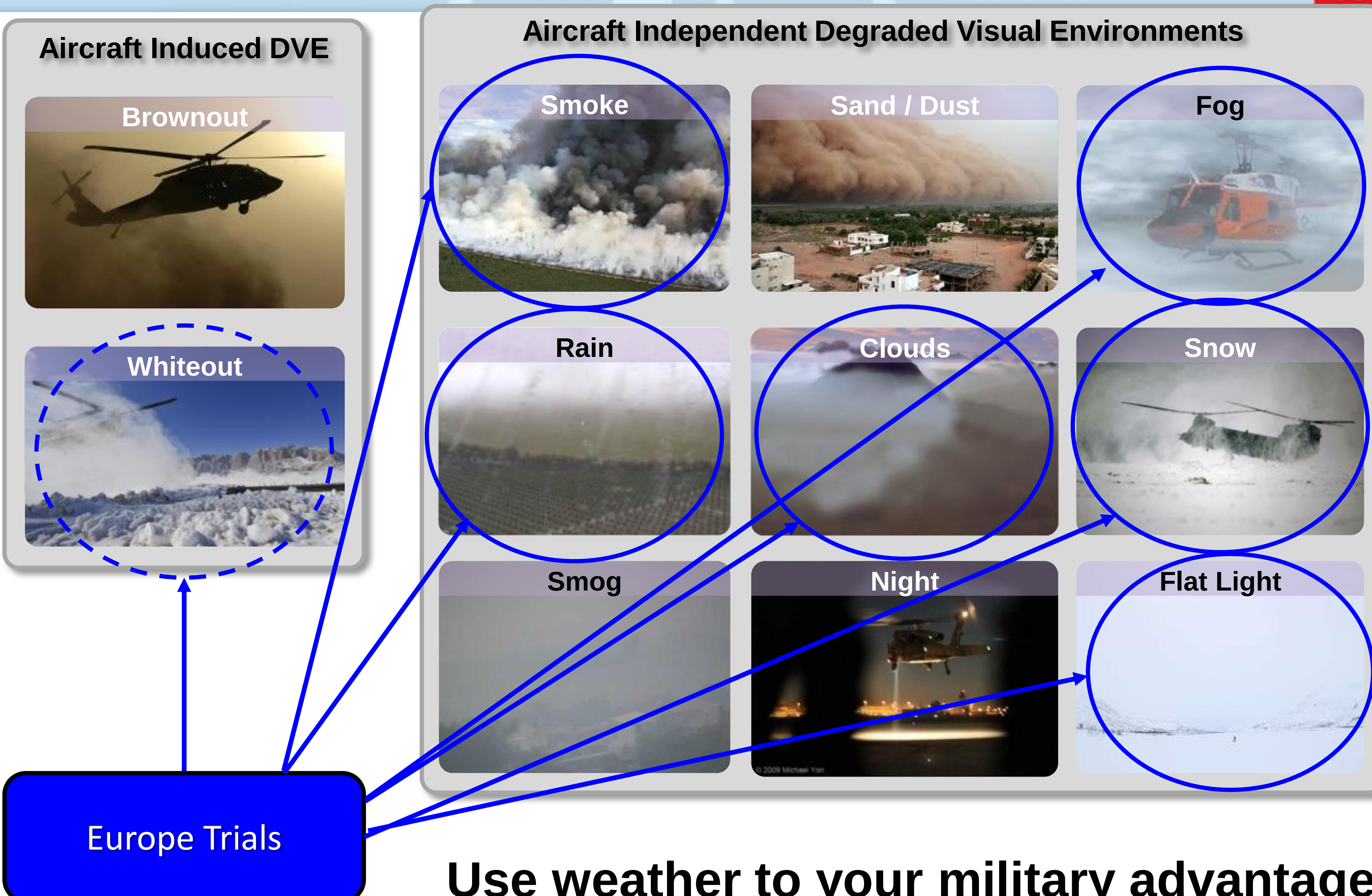
Conclusions from Yuma

Integrated system of terrain/obstacle imaging sensors, flight control, and pilot cueing was successfully demonstrated.

- Sensors provided a stable image of terrain/obstacles in the dust. However, workload was too high for the pilot on the controls to interpret the image. Small obstacles lost in clutter.
- Collective coupling improves performance and reduce workload. However, workload still too high to interpret sensor image. Need to investigate benefits of coupled cyclic.
- Test could not have been done without landing guidance and symbology cueing. Aural cueing complemented symbology.

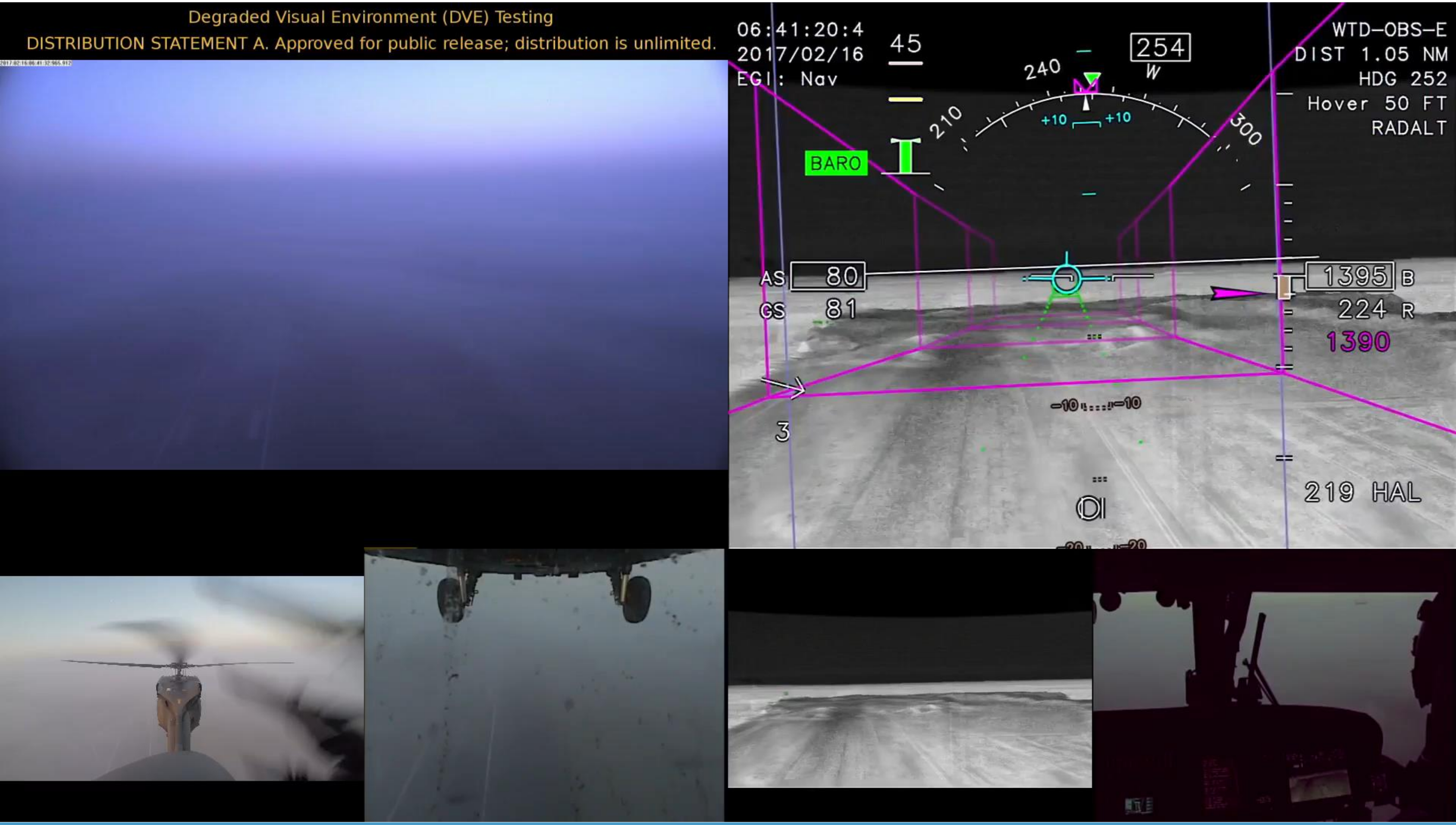
Video of NATO Trial in Germany

- NATO sponsored flight trials in DVE conditions using LOE #1 Sensor
  - Rain/fog/clouds at WTD-61, Manching, Germany
  - Whiteout at Ällgialp from Militärflugplatz Alpnach, Switzerland
- 25 Total flights (30.5 flight hours) conducted from 1-27 February in Germany and Switzerland
- US system received feedback from 12 foreign XPs (6 Swiss, 4 German, 2 UK)

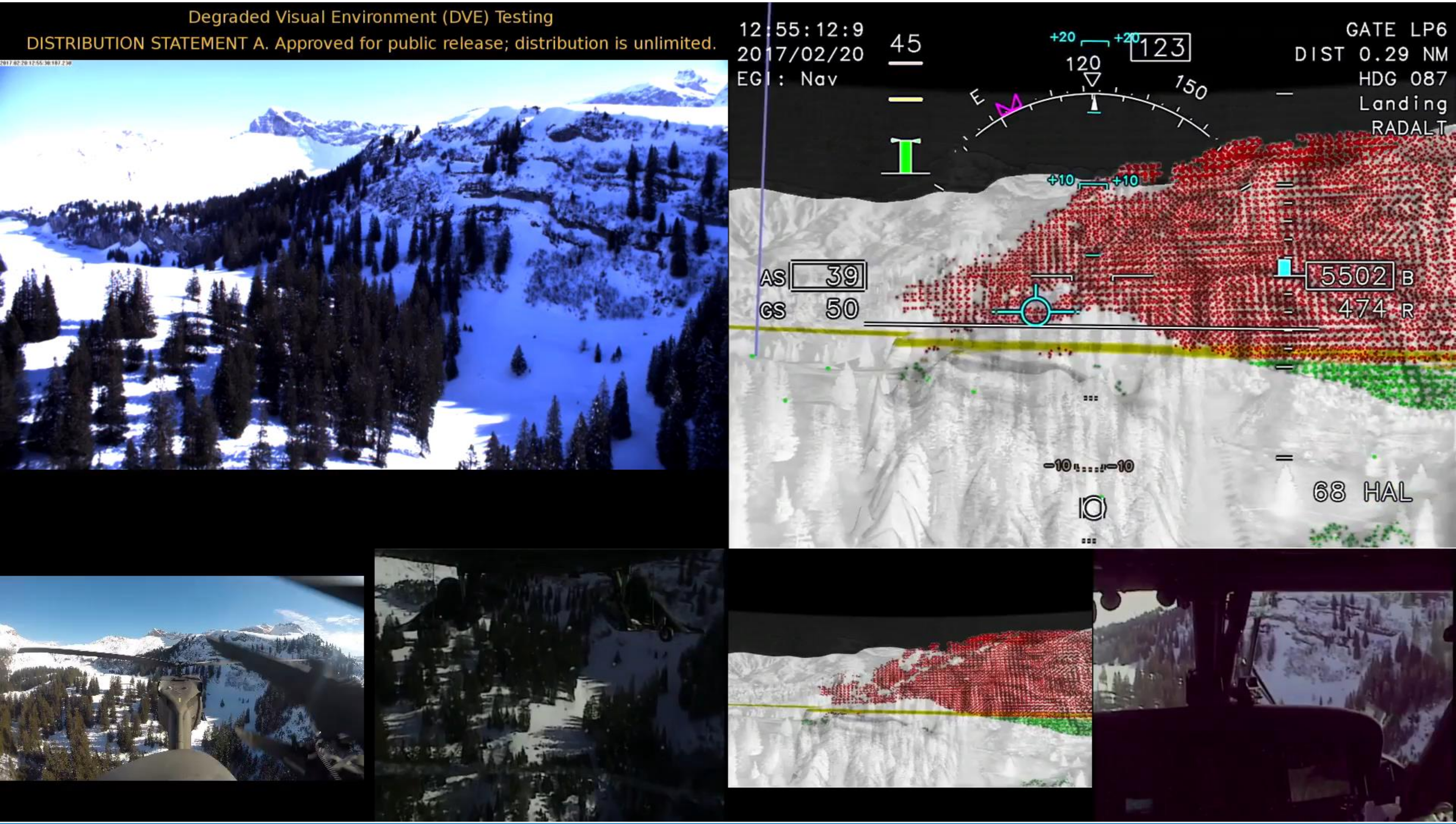


Use weather to your military advantage.

Video of NATO Trial in Germany



Video of NATO Trial in Switzerland



Questions?

Bedford Workload Rating for Obstructed Landings