Overview

- Background (Helicopter Brownout)
- Requirements
  - Mishap Analysis
  - Operational Tasks
- Solutions Analysis
- Conclusion
# Solutions Analysis for Helicopter Brownout 9th SE Conference

**Author(s):**

Air Force Institute of Technology  
2950 Hobson Way WPAFB, OH 45433-7765

**Performing Organization Name(s) and Address(es):**

Air Force Institute of Technology  
2950 Hobson Way WPAFB, OH 45433-7765

**Distribution/Availability Statement:**

Approved for public release, distribution unlimited

**Supplementary Notes:**

The original document contains color images.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Report</td>
<td>unclassified</td>
<td>SAR</td>
<td>15</td>
</tr>
<tr>
<td>b. Abstract</td>
<td>unclassified</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. This Page</td>
<td>unclassified</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Abstract:**

The original document contains color images.
Hovering Flight
Not as easy as it looks

Changing flight dynamics during approach to hover require large control inputs

All 3 Controls are Interdependent

Flight Controls
Main Rotor Thrust Axis
Main Rotor Thrust Magnitude
Directional Control Inputs (Anti-Torque)

Flight Regime
Static Instability
Dynamic Instability
Constant Perturbations

Detect Aircraft Position & Motion State
Assess Desired vs. Actual State
Continuous Control Loop
Make Control Inputs
Pitch + Power ≠ Aircraft Control

The Question
How to safely perform a vertical landing when you can't see outside due to recirculating dust/snow?

Do something different to keep visibility

or

Replace and/or degrade the effects of lost information
Do Something Different to Keep Visibility

- Land fast to stay ahead of the dust cloud
  - Requires suitable long flat/smooth LZ
  - Requires High Decel Rates at touchdown
  - Dependent on surface winds
  - Aircraft Specific
    - Allowable Landing Attitude (Deceleration)
      - H-60, H-46, H-47 Good (Tail Wheels)
      - MH-53M, Bad (No Tail Wheels)
  - May or may not work out well in formation

Do Something Different to Keep Visibility

Sometimes it works…
Do Something Different to Keep Visibility

Sometimes it doesn’t work

Replacing Lost Information
(and degrading loss of capability)

Aircraft State
Drift Vector
Altitude
Attitude

LZ Suitability
Size/Shape
Obstacles
Surface/Slope

Awareness

Hazard
Proximate Obstacles
Other Aircraft

Navigation
LZ Range/Bearing
Ingress Path
Egress Path

Landing Safely and Effectively
Achieve Combat Mission Objectives

Make Decisions
Decide what to do with the aircraft

Maintain Aircraft Control
Make the aircraft do what you want it to
Replacing Lost Information  
(and degrading loss of capability)

- Aircraft Navigation Systems  
  - GPS/INS, Doppler, Radar Altimeter  
  - Mission Computer (Waypoint Navigation)

- Low Speed Aircraft Control Symbology  
  - Drift Vector, Vertical Velocity, Altitude, Heading, etc.

- Geospatial Information (What’s out there?)  
  - Digital Map (Imagery, Terrain, etc.)  
  - Sensor Information (FLIR, Radar, etc.)

- Reduced Aircraft Control Workload  
  - Stability Augmentation  
  - Self Contained Approach Guidance  
  - Coupled Approach/Hover Capabilities

V-22 Hover Display

What can be done to improve the situation?

Mishap Analysis  
Long known problem, just more prevalent

- 33 Identified USAF Mishaps (1971 – 2006)  
  - Loss of effective visibility causal  
  - Landing/Takeoff phase of operations  
  - HH-3E, MH-53H/J/M, HH-60G & UH-1F

- Mishap Costs  
  - $72M Total pre 9/11 (30 Years)  
  - $72M Total post 9/11 (5 Years)  
  - DoD Costs estimated at $100M per year

- Mishap Factors  
  - Inadequate Aircraft Control  
  - Undetected Surface Hazards  
  - Undetected Lateral Obstacle

1980 - Desert One (Operation Eagle Claw)  
Failed rescue of American hostages, Iran

CSAR-X (~$45 Million)

CV-22 ($80+ Million)
Conclusions

- Maintaining aircraft control is Problem #1
- Better awareness of hazards is important
- Reducing aircraft control workload is key if added sensor information is to be effective
- Capabilities/Tactics that allow zero roll vertical landings could significantly reduce mishaps due to surface hazards

Measurable Requirements

Define Core Performance Tasks

Define Sub-Measures

Define Utility Curves

Define Weighting Tree

Sensitivity Analysis

Validate & Iterate as Required

Used to compare relative value between alternative solution sets

Starting point for tech demo system development

Framework for future combat system development
Major Tasks & Attributes

• Core Operational Tasks
  – Maintain Geospatial Awareness of Intended Landing Point
  – Confirm LZ Size & ID/Refine Landing Point
  – Locate Surface Hazards
  – Locate Proximate Obstructions
  – Successfully fly to safe landing point and land/hover as required

• Other Requirements (System Attributes)
  – Human Factors
  – Programmatic
  – Physical Characteristics
  – Sustainability
  – Operating Environment

Note: Related requirements sources: AFSOC No/Low Visibility ICD, Cable Warning/Obstacle Avoidance ICD, CSAR-X CDD

Core Operational Tasks (OV-5)
Execution Timeline

1. Maintain Geospatial Awareness
2. Assess LZ
3. Locate Surface Hazards
4. Locate Proximate Obstructions
5. Maintain Aircraft Control
Weighted Objectives Hierarchy

Other Factors (Cost, Size, Weight, etc.)

Performance

5 Core Tasks

Sub-Measures

Solutions Analysis
Process Overview

Define Solution Architecture → Identify Solution Component Categories → Assess Component Options → Define Notional Baseline Aircraft

Validate & Iterate as Required

Build Solution Matrix

Select Configs For Eval → Evaluate Solutions → Sensitivity Analysis → Conclusions
Objective System Architecture (SV-1) & Focus Areas

The Notional Baseline Aircraft

(MH-53M + HH-60G + CSAR-X + CV-22)

4

INS/GPS
Turreted FLIR
Radar Altimeter
Digital World Model
(Digital Map)

Mission Computer / Flight Director
Automatic Flight Control System
(Waypoint Nav & Coupled Approach)

Cockpit Digital Displays (VSD/HSD)
External Sensors
Range, Resolution, Penetration

### 3D Capable
- 3D Active MMW
- LADAR
- Sparsely Populated Radar Array
- IFSAR
- Active Acoustic System
- Image Stereo Pair Modeling

### 2D Capable
- IR Video
- Image Intensified (I² Video)
- Fused IR/I² Video
- 2D Active MMW
- Passive MMW (w/ external illuminator)
- Passive MMW
- SAR
- Geo-rectified Digital Image

### Preloaded Data
- Digital Terrain
- Vertical Obstruction Data
- Digital Maps & Imagery (CIB)

### Other Systems
- **Station Keeping Equipment** (range/bearing)
- **DataLink** (aircraft range/bearing + sensor data)

### Primary Solution Option
- Technology Interest Area

---

Human Interfaces
Enabling Effective Task Performance

- HMD
- Head Tracked HMD
- HDD
- Tactile
- 3D Audio

### Symbology
- Foveal Symbology
- Peripheral Symbology
- HSD Views (Hazard Presentation)

### Maps
- Hazard Warning
- Enhanced Vision System (EVS)
- Digital Terrain/Synthetic Vision System (SVS)

### Video
- Fused View (EVS + SVS)

---

### Primary Solution Option
- Research Area
Aerodynamics & Flight Controls
Effective Aircraft Control

**Manual Aircraft Control**
Self Contained Approach Guidance
**Improved Low Speed Stability** *(Handling Qualities)*
Performance Based Flight Controls
Approach Guidance with Enhanced Obstacle Avoidance

**Coupled Aircraft Control**
Coupled Hover
Coupled Approach
**Coupled Approach with Enhanced Obstacle Avoidance**

**Aerodynamics**
Modeling & Simulation
Visible Null Areas *(H-101 & H-53E)*

**Flight Controls**
No Addition
Improved Aircraft Handling Qualities
Coupled Approach with Enhanced Obstacle Avoidance
Coupled Approach with Enhanced Obstacle Avoidance + Improved Aircraft Handling Qualities

**Sensors**
No Addition
Sparse Array
MMW
LADAR
Sparse Array + MMW
Sparse Array + LADAR
MMW + LADAR
Sparse Array + MMW + LADAR

**Human Interface**
No Addition
Helmet Mounted Display *(Symbology)*
Head Tracked HMD *(Video & Symbology)*
3D Audio & Tactile
HMD + 3D Audio/Tactile
Head Tracked HMD + 3D Audio/Tactile

Solution Configuration
Matrix of 192
**Selecting Solution Configurations for Evaluation**

Resource/Time Constrained (Can’t Assess all 192)

- Assess Acquisition Likelihood (Cost Balance, Synergy)
- Select Minimum Matrix Sample (Design of Experiments)
- Select Additional Configurations Based on Likelihood

**System Configuration Assessment**

Generating Relative Solution Value

- Assess Quantitative Component Measures (Sensor Range, Weight, etc.)
- Assess System Measures (Quantitative & Qualitative)
- Generate Individual & Composite Utility Values
Evaluate Solutions

• Sensors
  – Millimeter Wave System
    • Low Task Performance
    • High Cost & Size/Weight
  – Sparse Array
    • Moderate Task Performance
    • Low Cost & Size/Weight
  – LADAR
    • High Task Performance
    • High Cost & Size/Weight

• Human Interfaces
  – Head Tracked HMD
    • Slim Benefit in High Cost Solutions
    • Slim Penalty in Low Cost Solutions
  – 3D Audio/Tactile
    • Penalty in Low Cost Solutions
    • Neutral in High Cost Solutions
    • High Cost for Stereo ICS

• Flight Controls
  – High Benefit
    • Improved Handling Quality -> Enhanced Ops
    • Both > Either

Sensitivity Analysis
Performance vs. Other Factors (Cost, Weight, Etc.)

Performance/Other Solution Value Sensitivity

Performance vs. Other Weighting Ratio

50-50  55-45  60-40  65-35  70-30

SOCOM
Army / USMC
Helicopter Brownout Conclusions

• High Performance System (SOF)
  – Sparse Radar Array + LADAR Sensors
    • Fusion Processing & Persistent 3D World Model
  – Head-tracked Helmet Mounted Display
    • Symbology
    • Enhanced and/or Synthetic Vision

• Lower Performance System (Conventional)
  – Sparse Radar Array
  – Helmet Mounted Display (Symbology)

• Flight Control Systems & Guidance
  – Handling Qualities
  – Flight Directed & Coupled Approach Capabilities
  – Assess and Develop per Aircraft MDS
    • Tiltrotor vs. Helicopter Issues
    • Digital FCS vs. Augmented Mechanical Controls

SE Wisdom

• Clear measurable requirements are the most useful in situations when they are hardest to generate

• There is nothing more potentially complicated than a blank sheet of paper
  – It is impossible to effectively consider and choose from an infinite number of design options when developing a new system
  – Overcome analysis paralysis with active management and hard decisions to create a manageable number of potential solutions

• Use systems engineers with actual ops experience
  – Operate in the Region of Effective Communication (REC)