DEPARTMENT OF
BEHAVIORAL SCIENCES AND LEADERSHIP

UAS Control From a Moving Platform - A Preliminary Simulator Study

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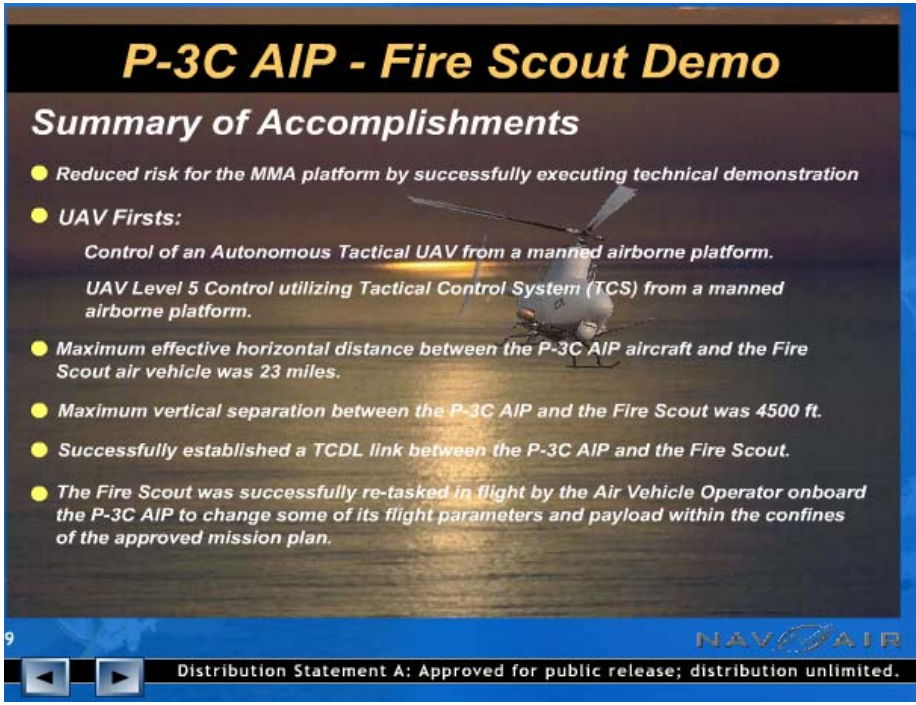
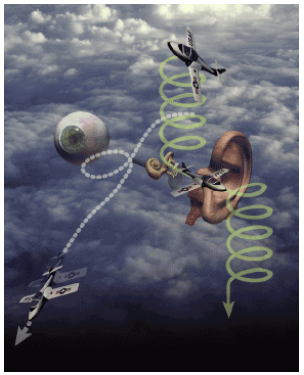
Background

- As UAS operations continue to expand, operational needs may dictate airborne control of UASs
  - Dec 2003 Navy demo of Fire Scout controlled from P3C AIP http://uav.navair.navy.mil/
- Several other possible platforms possible
  - C-130 variants, JSF?
- Will control platform motion affect UAS control?



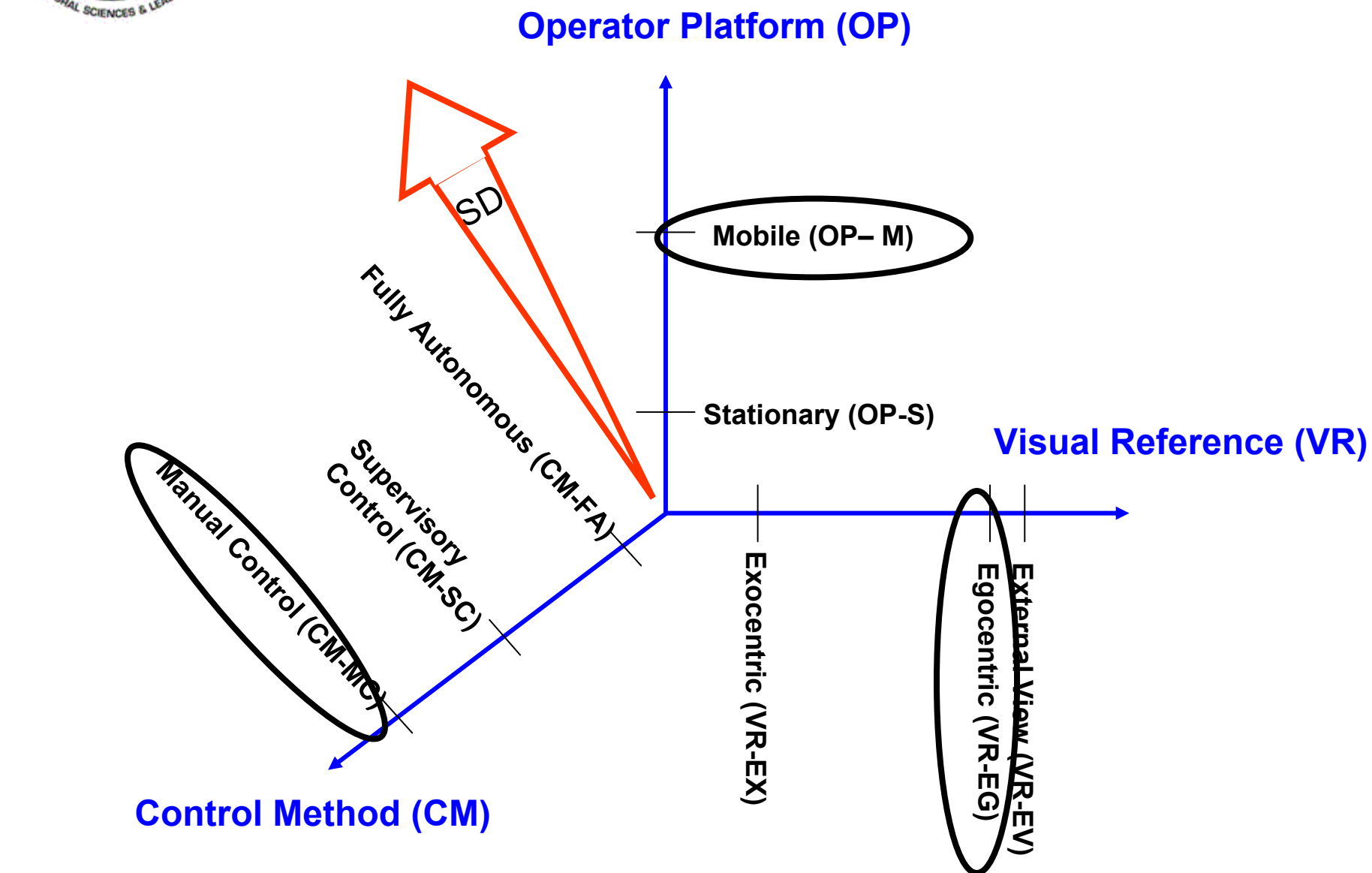
Spatial Disorientation
(Self, Ercoline, Olson, Tvaryanas; 2006)



- **Spatial Disorientation (SD)**
  - **Definition:** A failure to sense correctly the attitude, motion and/or position of the aircraft with respect to the surface of the earth (Benson 1999)
  - ***Even though the UAS operator is not located in the vehicle, he or she can still experience spatial disorientation - Control interference may be initial manifestation of insipient spatial disorientation***

Example : "Mishap pilot (MP) was conducting a night visual approach and landing. Thinking he was on the runway, MP released back pressure on the control stick while still 12 feet above the runway. The MUAV touched down nose gear first."

Spatial Disorientation Model (Self, Ercoline, Olson, Tvaryanas; 2006)



Previous Research

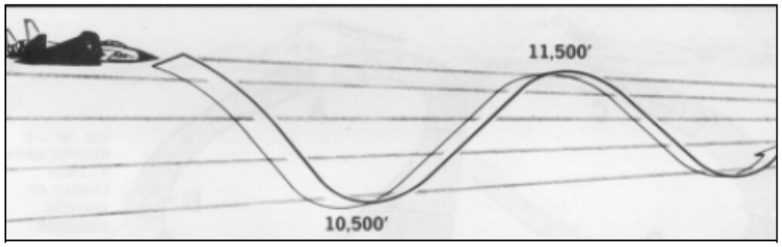
- **Reed (1977) – Cue Conflicts in controlling RPVs from a moving platform**
  - **Motion limited to simulated turbulence**
  - **Results**
    - **Platform motion not easily ignored**
    - **Incompatible motions interfered with control**
      - More errors, longer response times
    - **Previous flight experience did not mitigate these effects**
    - **Need for motion simulation in training**

Study Goal

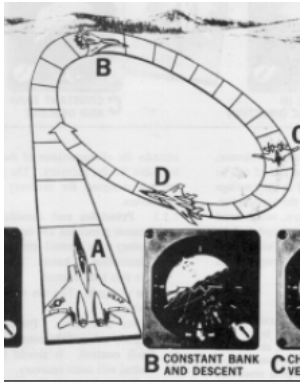
- **Preliminary exploration of the effects of control platform motion on vehicle control**
  - **Hypotheses**
    - **Presence of both visual and motion cues would exacerbate observed difficulties**
    - **Motion incompatible with UAS flight path will be most disruptive**

Design

- **Subjects - 10 military pilots on Faculty/Staff at USAFA**
  - Averaged over 10 years of flight experience across a variety of platforms
- **Tasks – Simulated UAS flight task (Microsoft Flight Simulator 2004)**
  - Vertical Task = constant 1,000 fpm rate climb and descent; constant heading



  - Turning Task = constant 30 ^{o} bank angle turn to right and left; constant altitude



Apparatus - Simulator

- **Simulator – General Aviation Trainer (GAT II)**
  - **Front Panel visual**
  - **Motion in roll, pitch, yaw**
    - **Simulator motion was controlled by experimenter**

Apparatus – UAS Task

- **UAS Task – Microsoft Flight Simulator 2004**
  - **Displayed on Dell Latitude laptop – 17” display screen**
  - **Aero model = Mooney Bravo**
  - **Joystick for UAS control**
  - **FSUIPC Data program (2Hz)**
    - **VVI, Altitude, Heading, Bank**

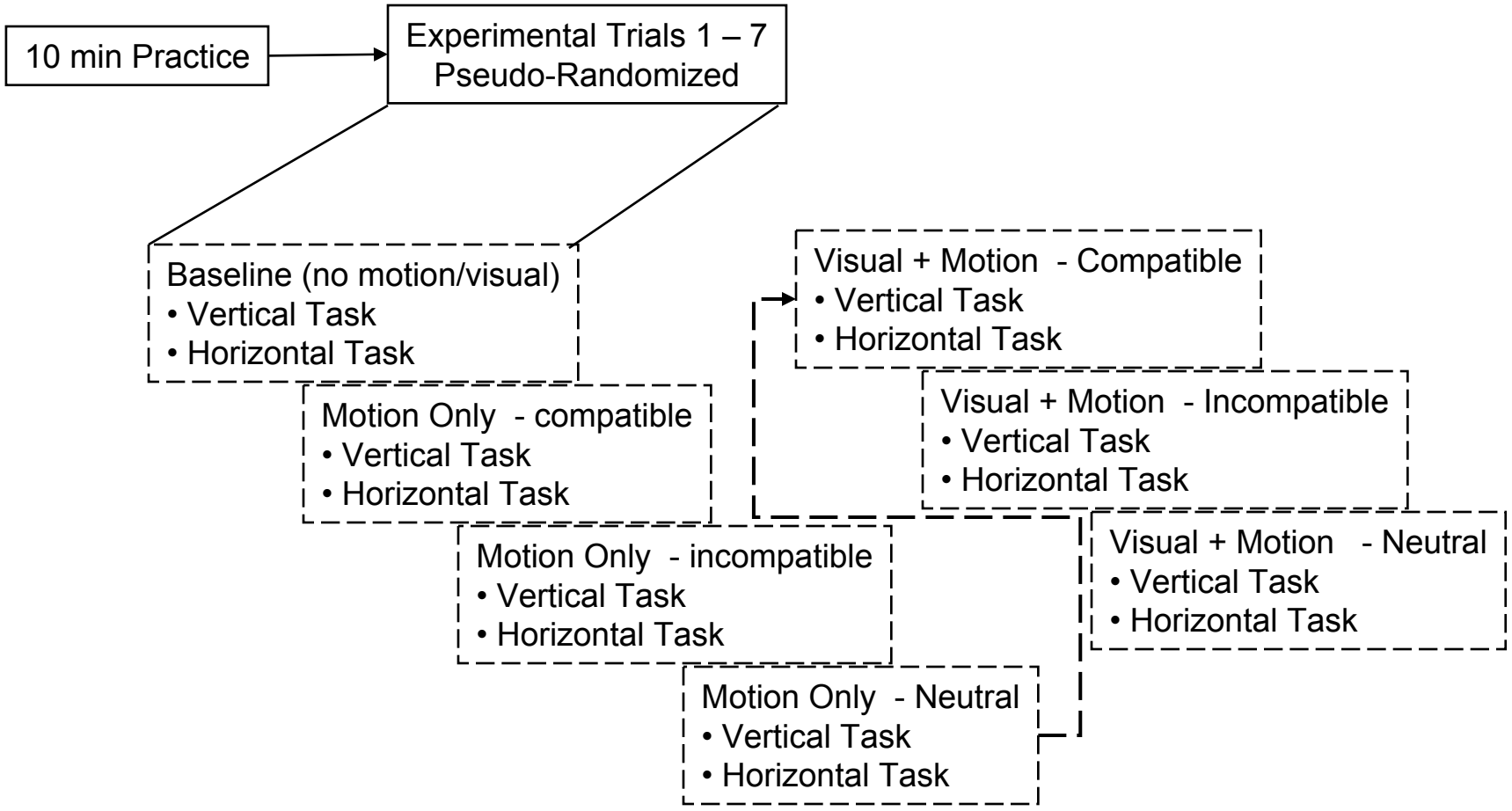
Task

Design

- **Independent Variables (all within subjects)**
  - **Platform motion – 3 levels**
    - **Baseline (no motion/no visual)**
    - **Motion only (no visual)**
    - **Visual + Motion**
  - **Direction of motion – 3 levels**
    - **Compatible – Motion of simulator in same direction as UAS flight task**
    - **Incompatible - Motion of simulator opposite to UAS flight task**
      - E.g., simulator descending in vertical climb task
    - **Neutral – Simulator motion in different plane of motion**
      - E.g., simulator turning during vertical task; climbing or descending during turning task

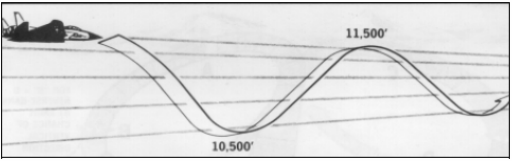
- **Dependent Measures**
  - **Vertical Task - VVI error, Heading error**
  - **Turning Task – Altitude error, Bank angle error**

Procedure


10 min Practice
Experimental Trials 1 – 7
Pseudo-Randomized
Baseline (no motion/visual)
• Vertical Task
• Horizontal Task
Motion Only - compatible
• Vertical Task
• Horizontal Task
Motion Only - incompatible
• Vertical Task
• Horizontal Task
Motion Only - Neutral
• Vertical Task
• Horizontal Task
Visual + Motion - Compatible
• Vertical Task
• Horizontal Task
Visual + Motion - Incompatible
• Vertical Task
• Horizontal Task
Visual + Motion - Neutral
• Vertical Task
• Horizontal Task

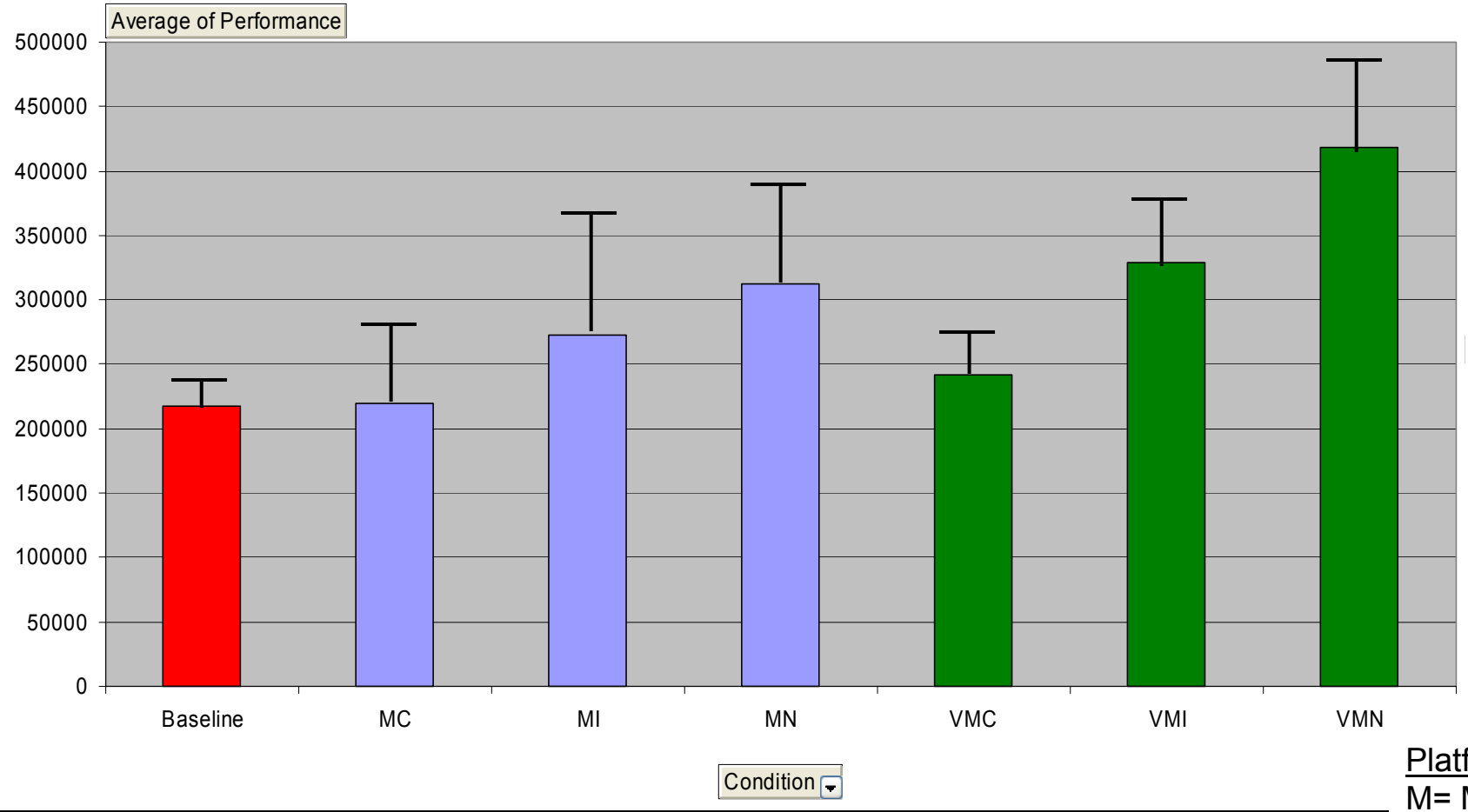
Results

- Repeated Measures ANOVA on control error measures
- Vertical Error Measures (Altitude, Vertical Velocity) showed significant and marginally significant effects
  - Platform Motion
    - Baseline < Motion Only < Visual + Motion
  - Direction of Motion
    - Compatible < Incompatible < Neutral
- Bank Angle Error also affected
  - Platform motion
    - Motion only < Baseline, Visual + Motion
- Will discuss by task
  - Vertical Task – VVI error and Heading Error
  - Turning Task – Bank Angle Error and Altitude Error



Vertical Task – 1,000 fpm climb and descent

VVI - MSE



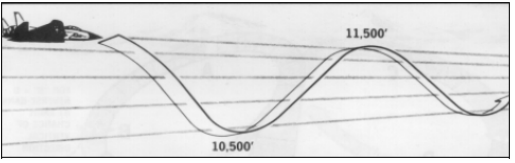
VMN > All except MN

VMI > VMC

Main Effect *p* = .137

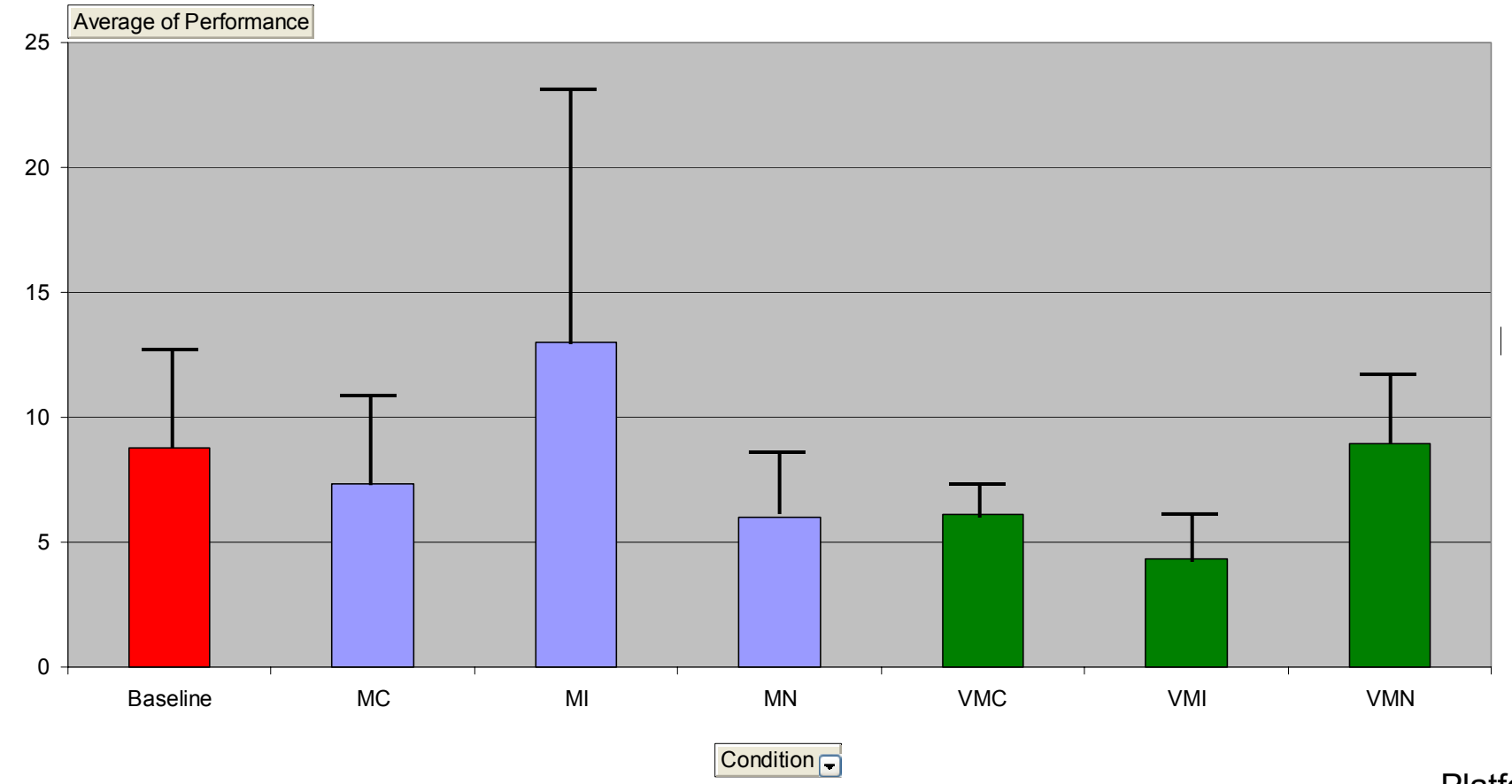
Platform
M= Motion
V = Vis + Motion

Motion
C = Compatible
I = Incompatible
N = Neutral



Vertical Task – 1,000 fpm climb and descent

Heading - MSE

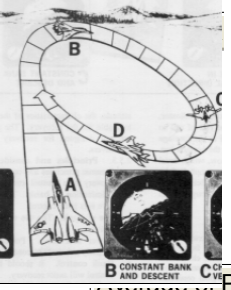


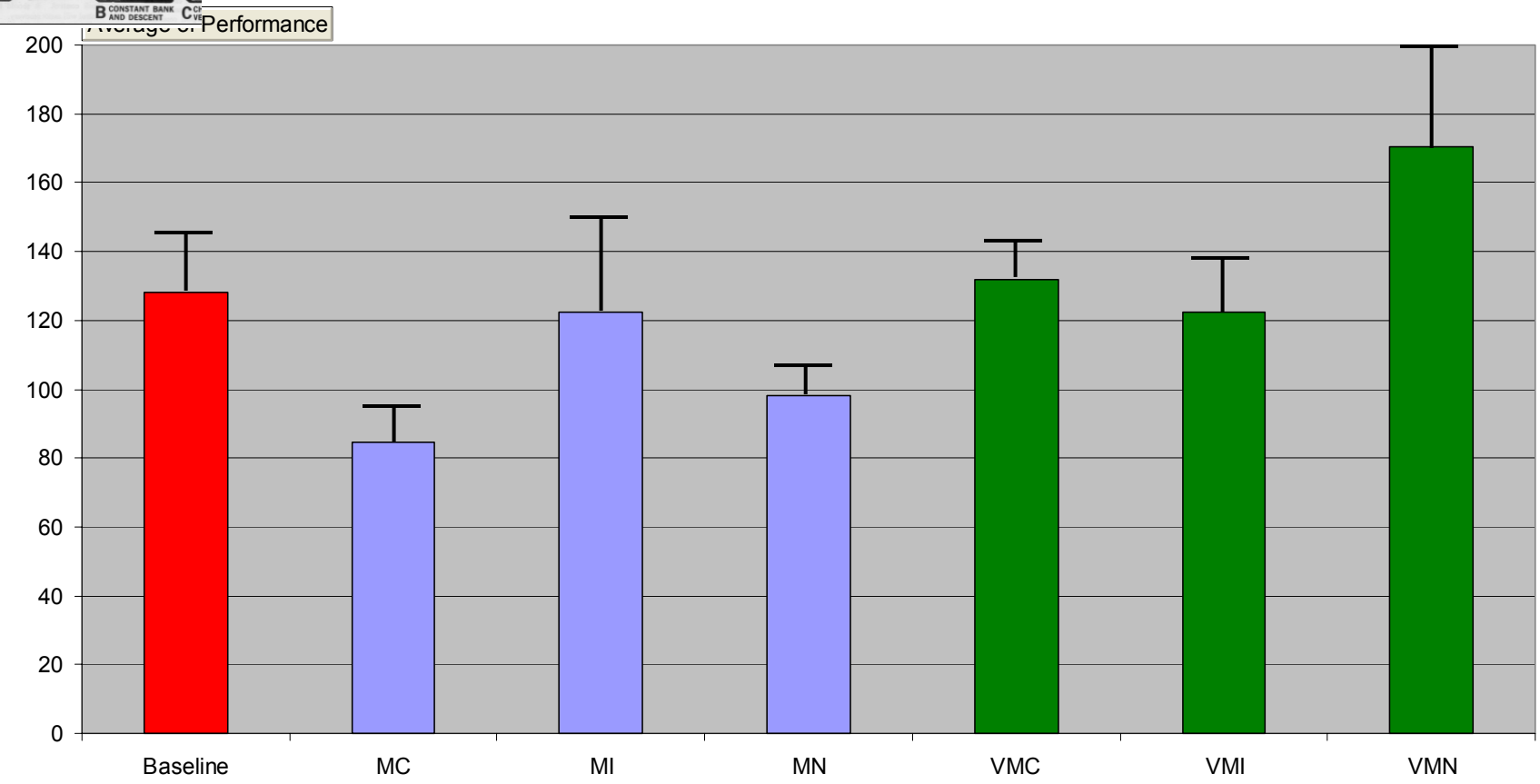
Main Effect p = .443

Platform
M= Motion
V = Vis + Motion
Motion
C = Compatible
I = Incompatible
N = Neutral

Turning Task – 30° bank turn

BANK - MSE





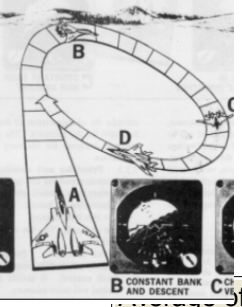
Baseline > MC, MN
MC < all but MN
VMC > MN, MC
VMN > all but MI

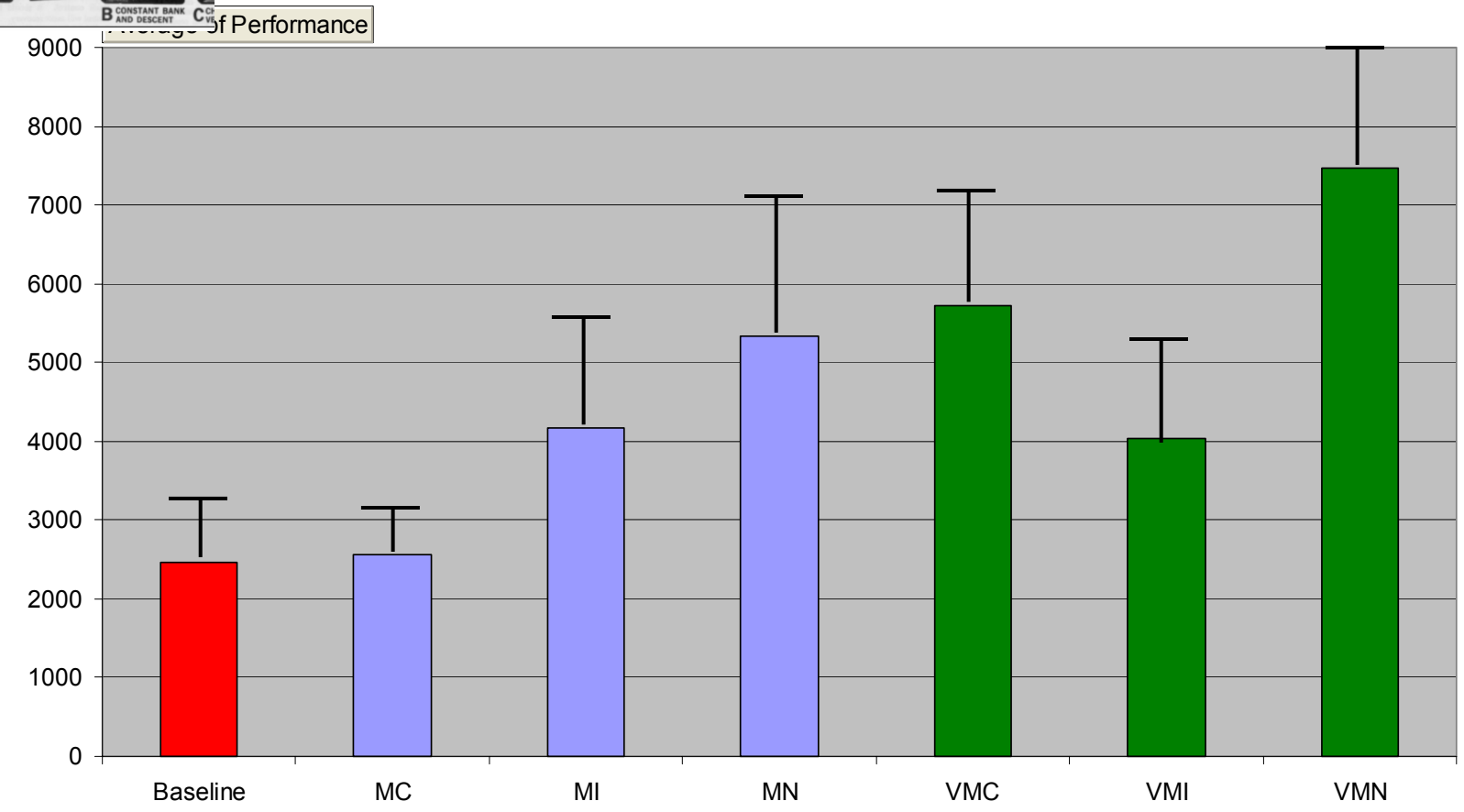
Main Effect p = .031

Platform
M= Motion
V = Vis + Motion
Motion
C = Compatible
I = Incompatible
N = Neutral

Turning Task – 30° bank turn

ALT - MSE





VMN > all but VMC, VMN

VMC > MC, Baseline

MN> MI, Baseline

Main Effect p = .008

Platform

M= Motion

V = Vis + Motion

Motion

C = Compatible

I = Incompatible

N = Neutral

Discussion

- Control platform motion type and direction does affect UAS manual control
  - Pitch axis control degraded, especially when platform motion is in a different plane of motion from UAS control task
    - Pitch axis autopilot may mitigate some effects
  - Motion in different plane most disruptive
  - Trend towards visual + motion resulting in most control interference
- Further study necessary – will take into a C-150 in Fall 06
  - Larger sample size
  - Turbulence?
  - Other UAS tasks

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