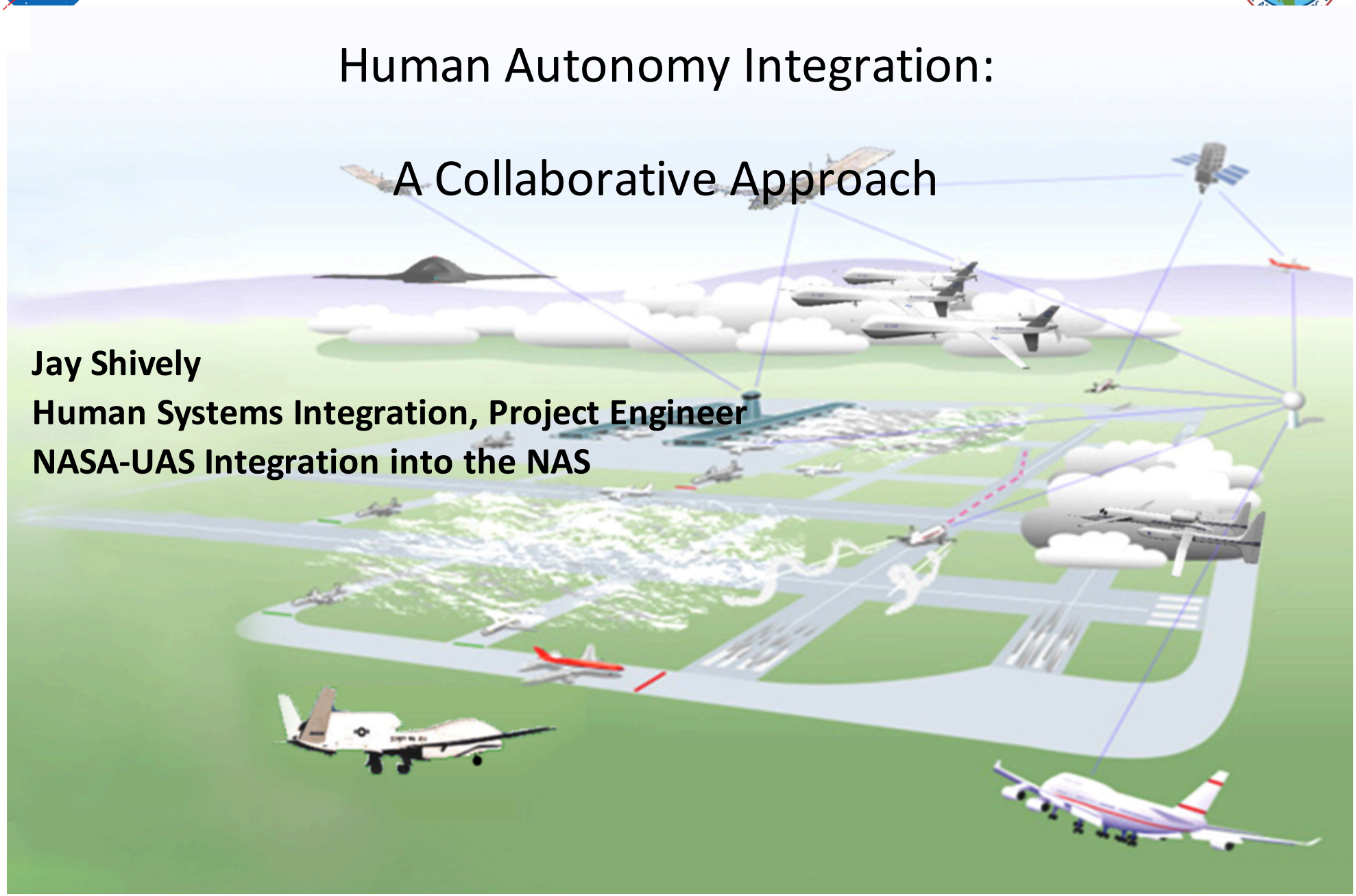
Human Autonomy Integration:

A Collaborative Approach



Jay Shively
Human Systems Integration, Project Engineer
NASA-UAS Integration into the NAS

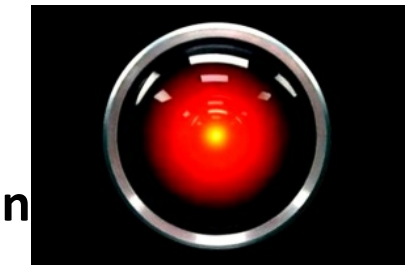
Outline

- Philosophy of Human-Autonomy Interaction
- Examples from the Workshop
- UAS Design extremes
  - Global Hawk
  - Reaper Ground Control Station
- A Brief Historical Review
  - Fitts
  - Sheridan & Verplank
  - Parasuraman, Sheridan & Wickens
- Dynamic context-driven collaboration

Automation – 2 Options

1) Follow the "Leftover" Principle

- Automate as much as possible
- Automate based on feasibility versus utility
- Design philosophy: automation will be always work as plann
- The human will take care of all 'leftover' tasks



2) Follow the User-Centered Approach

- Enable automation that supports human intent
- Flexible & adjustable automation
- Design for automation transparency &intuitive control
- Design philosophy: Human flexibly employs automation as needed

1 or 2 ??

- Littoral Battleship
- Autonomous car
  - "Solves everything … bad idea"
- UAS delivery systems
  - "Monitor" hundreds of "autonomous" UAS
- NASA projects

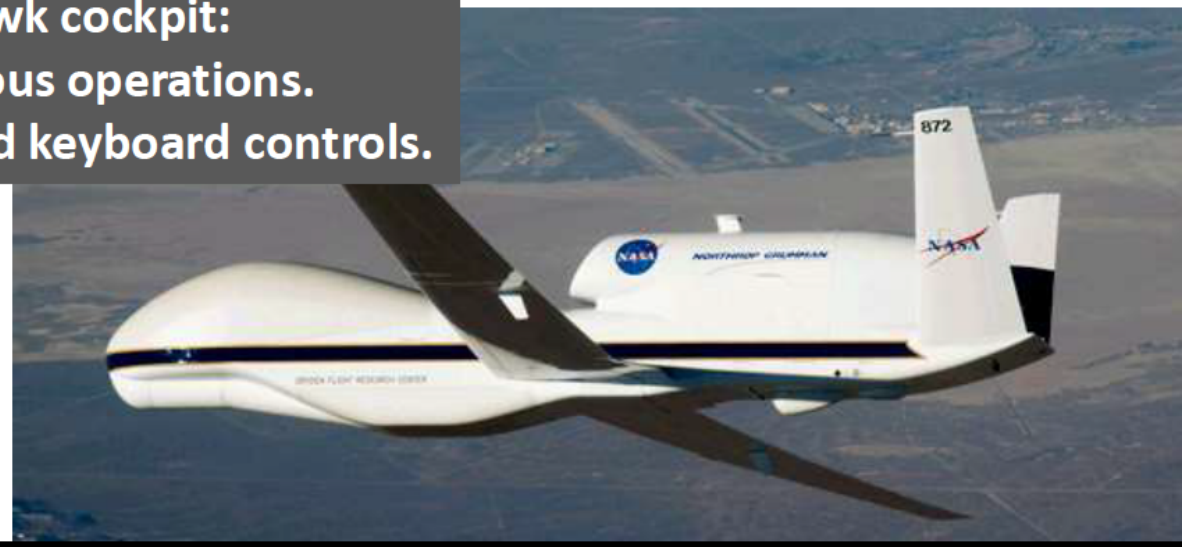
* Why ? Historical, focus – but this approach results in a different solution space

How can we replace the information ?

- You ***can't hear*** the engine rpm fluctuating
- You ***can't feel*** vibrations, accelerations or motion
- You ***can't smell*** the fuel leak
- You ***can't taste*** the electrical fire smoke
- AND, you ***lose vision*** in one eye, 30º FOV!
- WELCOME to UAS flying!

Is that a problem ?

Global Hawk cockpit:
Autonomous operations.
Mouse and keyboard controls.



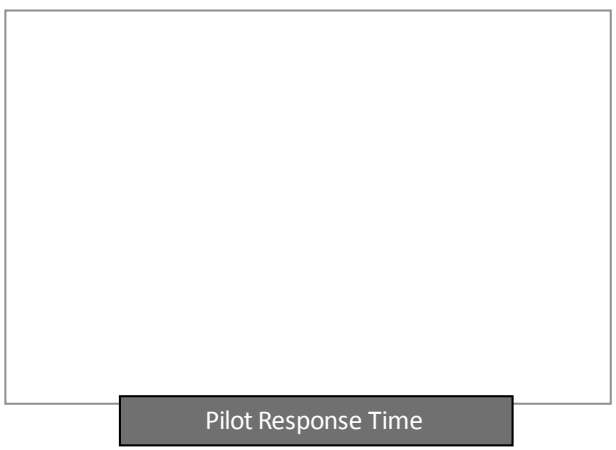
- Out of the loop phenomenon (Moray, 1986, Wickens, 1992, Endsley, 1995) (Cummings, Murphy, this workshop)
- Inflexible, brittle – NOT robust
- Contingency Operations
- Slower reaction to ATC/Alerts

Levels of Automation

Full Mission 1: The Effect of GCS Control Mode Interfaces

Ø **Objective**: to examine the effects of three different command and control (C2) interfaces on UAS pilots' ability to respond to ATC commands:

1. Waypoint-to-Waypoint only (WP; baseline)
2. Autopilot (quick input interface)
3. Manual (stick and throttle)



Pilot Response Time

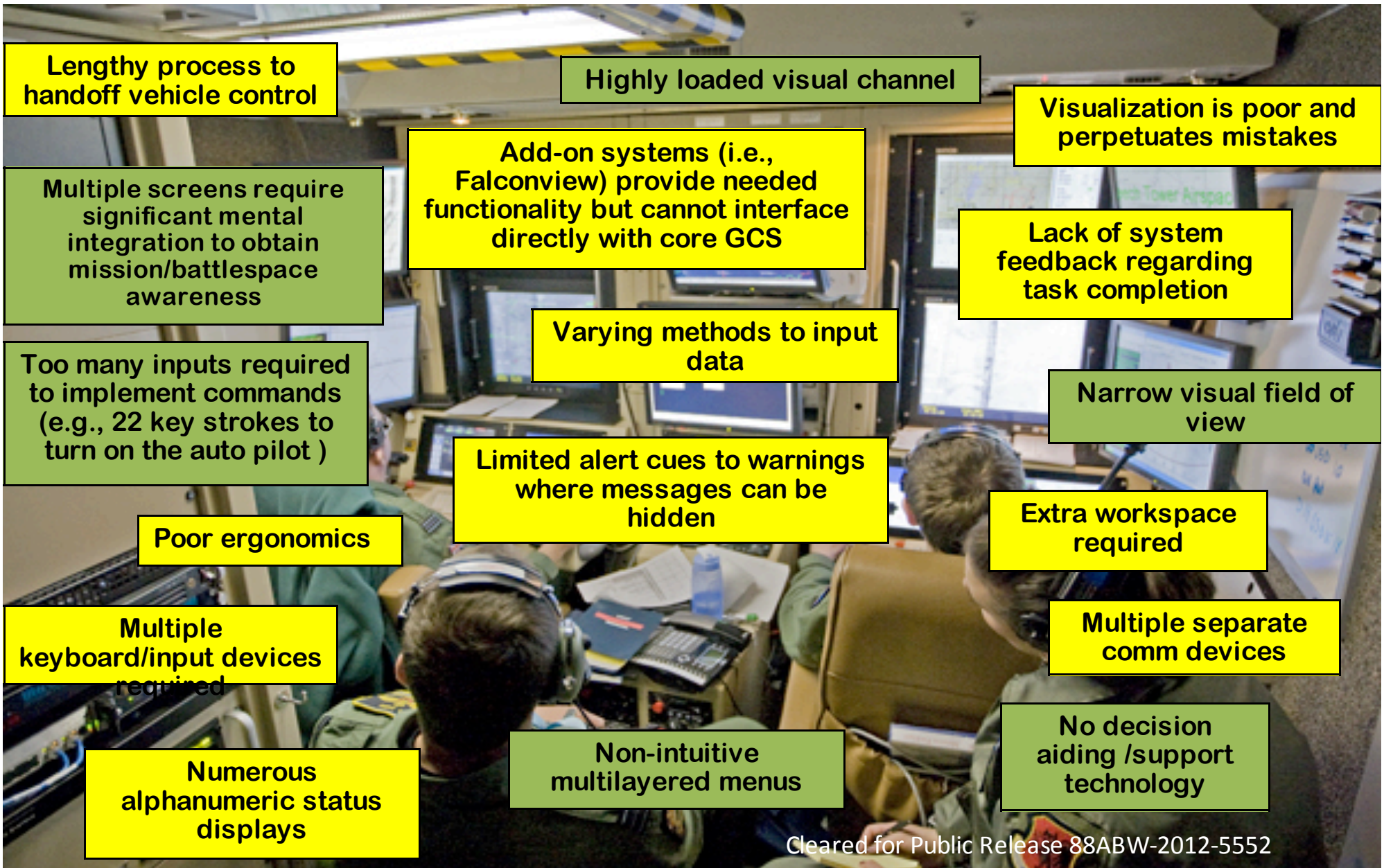
Pilot Edit Time

Main results/conclusions:

- Waypoint-to-waypoint control mode demonstrated significant deficits in all of the pilot measured response components compared to AP and M
- AP and M had significantly shorter compliance times overall than WP
- These results provide the initial database of expected pilot response time distributions, which will be critical to determining the Minimum Operational Performance Standards for UAS in the NAS
- Acceptability of C2 interfaces depends on the allowable response times given equipment performance specifications (i.e., sensors, aircraft performance, etc.)

Manual Solution: MQ – 9 Ground Control Station

Current UAV Operator Interface Issues



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TEAMING !!

Fully Autonomous –

Collaborative – >>>>

Fully Manual -

- Task Allocation
- Levels of Automation
- Levels of Processing
- Dynamic Context-Driven Collaboration

Paul Fitts

1912 – 1965, Ohio State University

- Fitt's Law
- Fitt's List (1951)

Humans appear to surpass present-day machines with respect to the following:

1. Ability to detect small amounts of visual or acoustic energy
2. Ability to perceive patterns of light or sound
3. Ability to improvise and use flexible procedures
4. Ability to store very large amounts of information for long periods and to recall relevant facts at the appropriate time
5. Ability to reason inductively
6. Ability to exercise judgment

Present day machines appear to surpass humans with respect to the following:

1. Ability to respond quickly to control signals, and to apply great force smoothly and precisely
2. Ability to perform repetitive, routine tasks
3. Ability to store information briefly and then to erase it completely
4. Ability to reason deductively, including computational ability
5. Ability to handle complex operations, i.e. to do many different things at once

Tom Sheridan

- Supervisory Control
- Levels of Automation (Sheridan and Verplank, 1978)

<u>Scale of Human-Machine Interaction</u>

Low 1. Whole task done by human except for actual operation by machine

2. Human asks computer to suggest options and selects from the options

3. Computer suggests options to human

4. Computer suggests options and proposes one of them

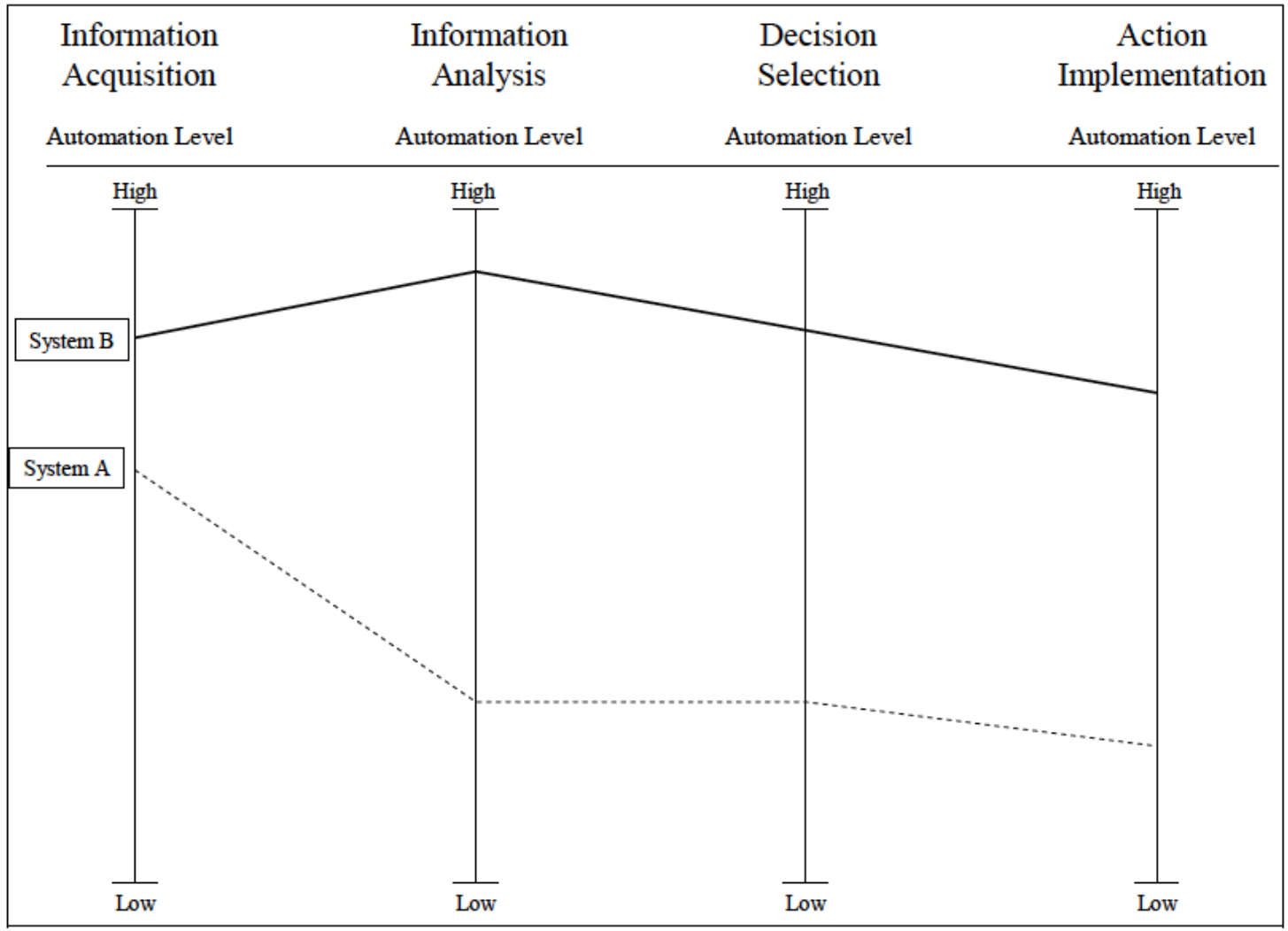
5. Computer chooses an action and performs it if human approves

6. Computer chooses an action and performs it unless the human disapproves

7. Computer chooses an action, performs it, and informs human

High 8. Computer does everything autonomously

Parasuraman, Sheridan & Wickens (2000)



Dynamic Context-Driven Collaboration

Defense Science Board – Stop focusing on levels of autonomy – Design Problem

Humans should flexibly and transparently move through levels/modes of automation as needed.

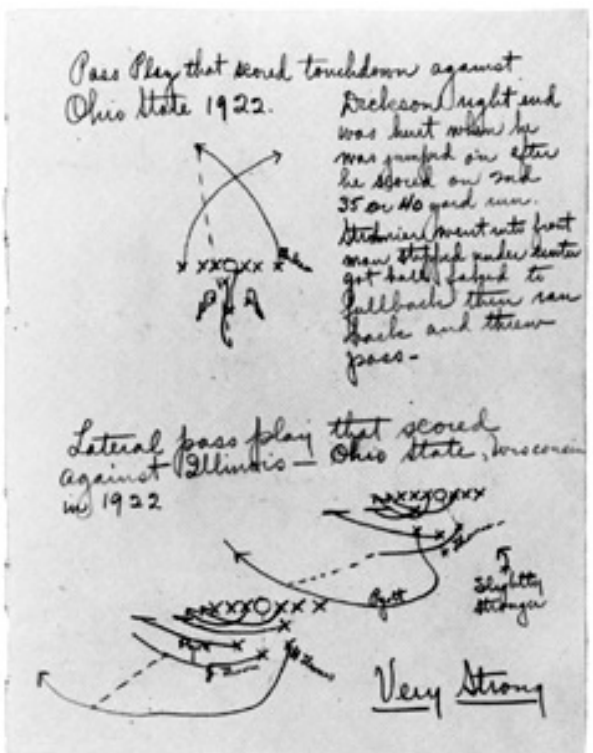
NOT static allocation

NOT static levels of automation

NOT only by Levels of Processing, but by context

- Optimal level varies not just with tasks, not just with levels of processing – but;
  - Mission
  - Driver capabilities/ state & trait
  - Context
    - Degraded operator
    - Rain
    - Snow
    - Dark

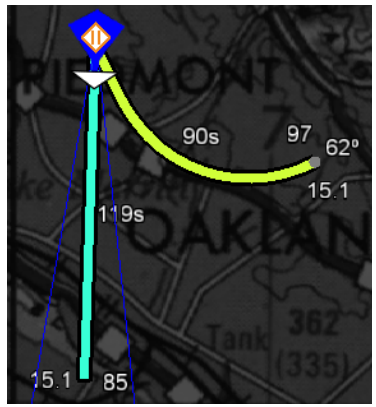
A Playbook® Approach to Delegation

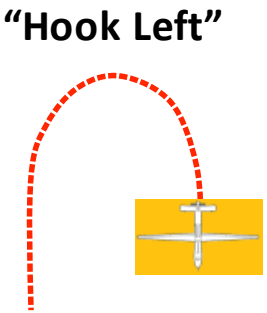


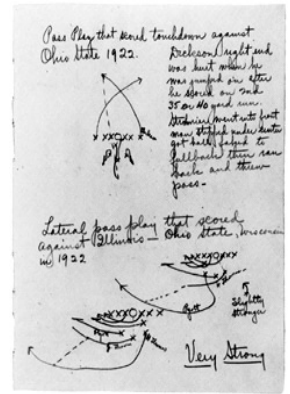
A page from Alonzo Stagg's 1927 Playbook

- A means of Delegation
- Plays contain an implicit goal
- Plays define a "template" of plan/behavior alternatives—a "space" of delegated planning authority
  - "pre-compiled" with convenient label
  - Supervisor can further constrain/stipulate as desired– by reference to play structure
  - Monitoring and information reporting facilitated by shared intent structure
  - Dynamic, real time revision and tuning = "calling signals"
- Subordinates responsible for best-effort attempts within play constraints

Multi-level Framework with Extended Playbook & Intermediate Candidate Control Modes (Draper, 2014)







Manual: Conventional "hands-on-throttle-and-stick" control.

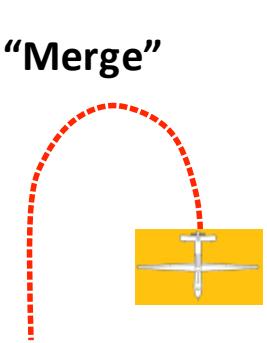
"Noodle": Pilot's inputs on stick & throttle defines RPA's near future path.

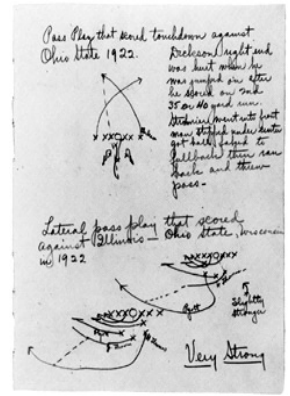
Lower Level Plays: Pilot's verbal command initiates short, simple maneuver.

Higher Level Plays: Pilot's verbal commands initiates a planning interaction with automation & then automates execution steps.

LOW ← LEVEL OF AUTOMATION → HIGH

Automotive Collaborative Human-Autonomy Teaming





Manual: Conventional "hands-on-throttle-and-stick" control.

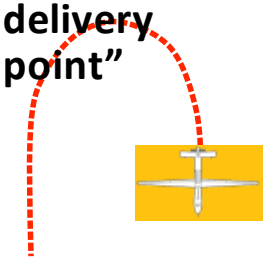
"Nudge": Stay a little farther away from that wall

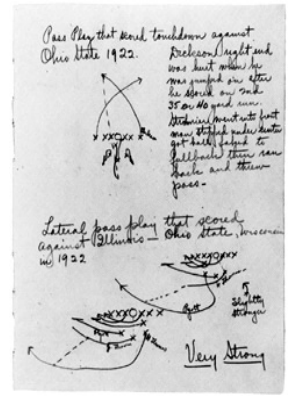
Lower Level Plays: Merge, maintain lane, We're third at the four way stop

Higher Level Plays: Take me home (the fastest, the safest, keep moving)

LOW ← LEVEL OF AUTOMATION → HIGH

Unmanned Delivery:
Multiple UAS could be at different levels





Manual:
Off-nominal – physically control.

"Nudge":
Move left 25' before dropping package.

Lower Level Plays:
Delivery point changed – re-route.

Higher Level Plays:
Re-route to avoid x,y,z due to high winds.

LOW ← LEVEL OF AUTOMATION → HIGH

Summary

- IF we believe that human-centered HAI is advantageous – then fully embrace
- Move away from prescriptive levels of automation (descriptive is OK)
- Build on the foundation of Fitts, Sheridan…
- Human-Autonomy TEAMING architecture is the key

Human role changing

- Away from just supervisory control
- NOT servants to automation overloads
- Collaborative Teammates !