

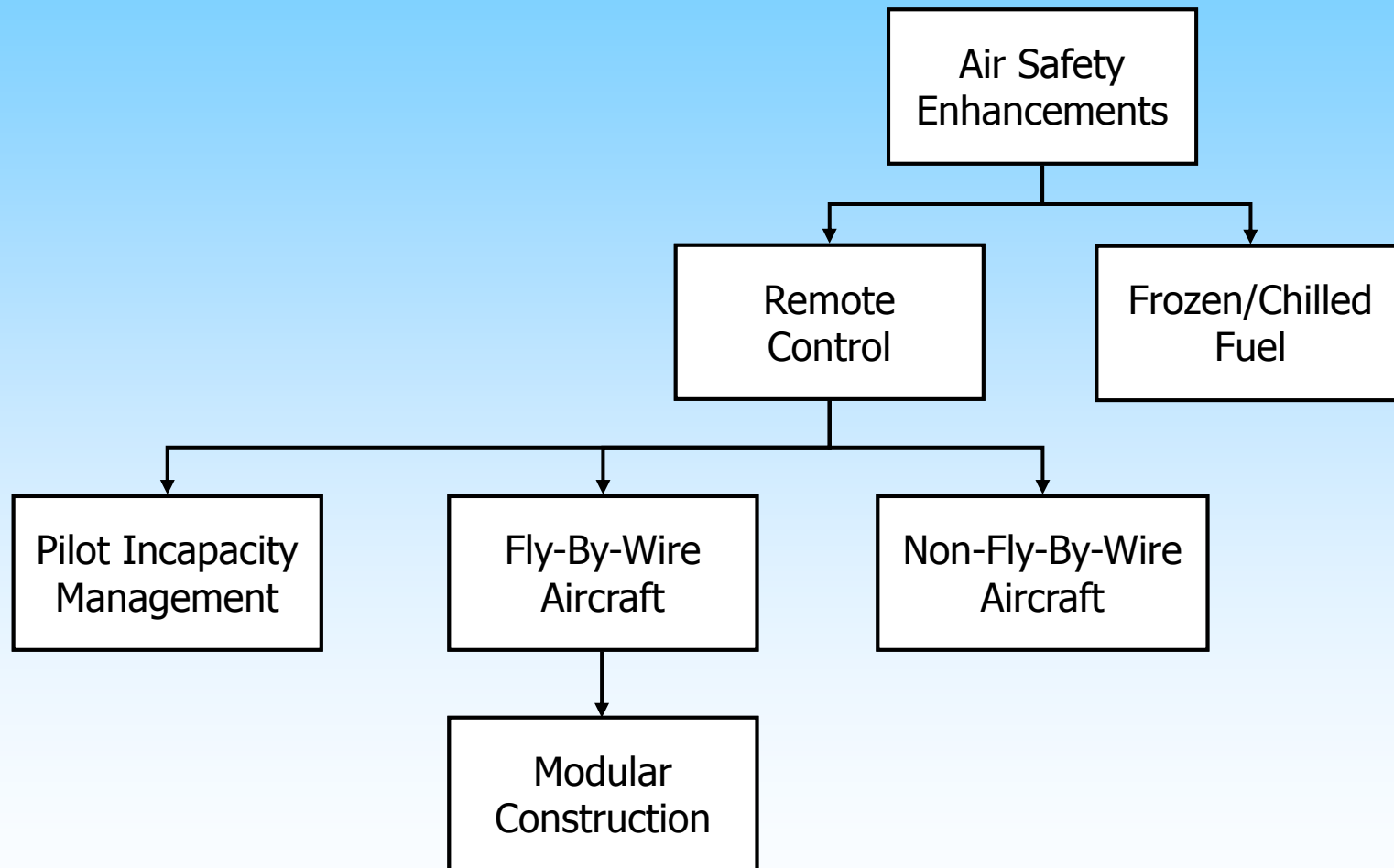
# Systems for Controlling Compromised Aircraft

Dr. Jeffrey A. Matos and Mr. Karl Milde, Jr.

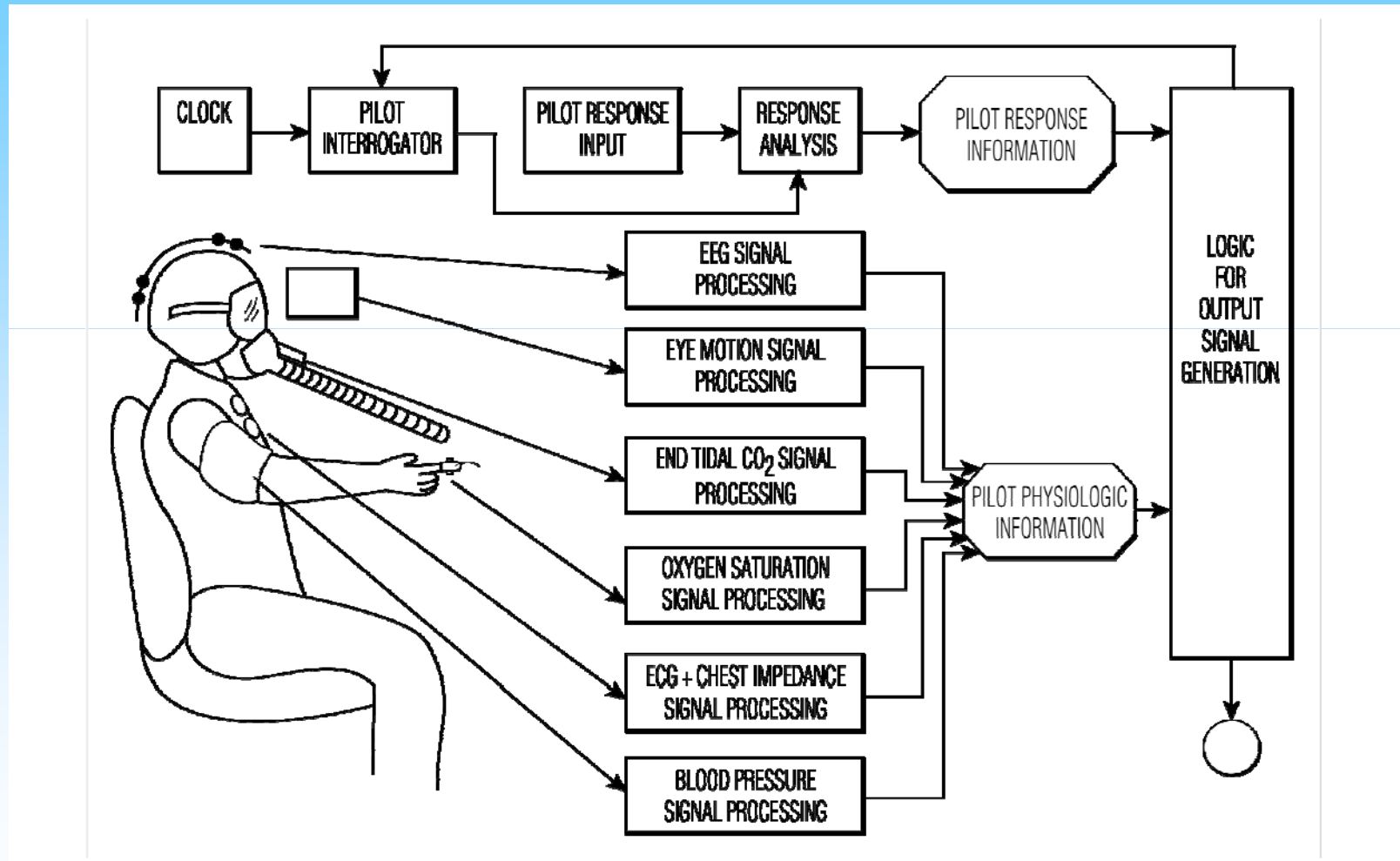
21 May 2007



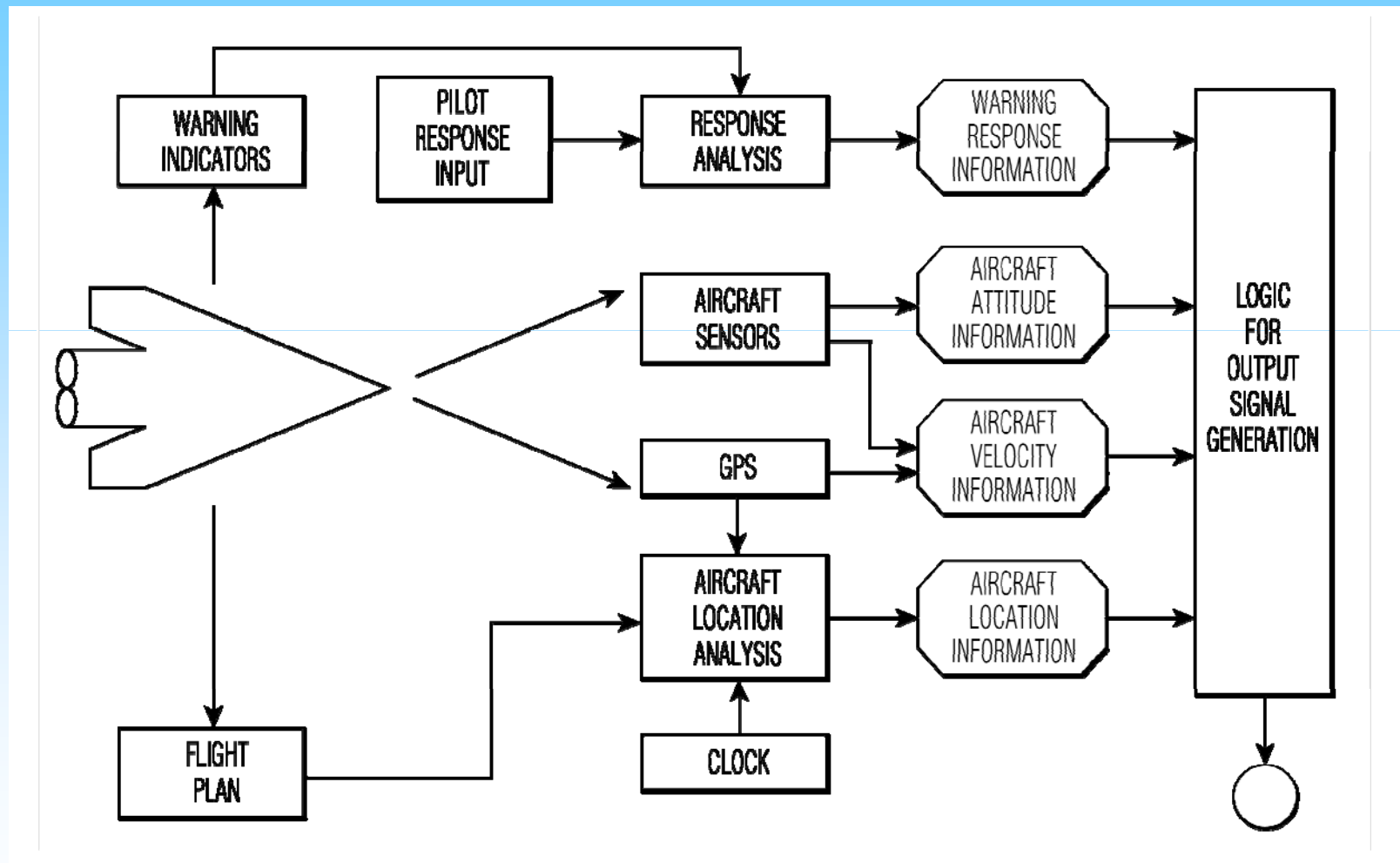
# Air Safety Enhancements



# Impaired Pilot Detection

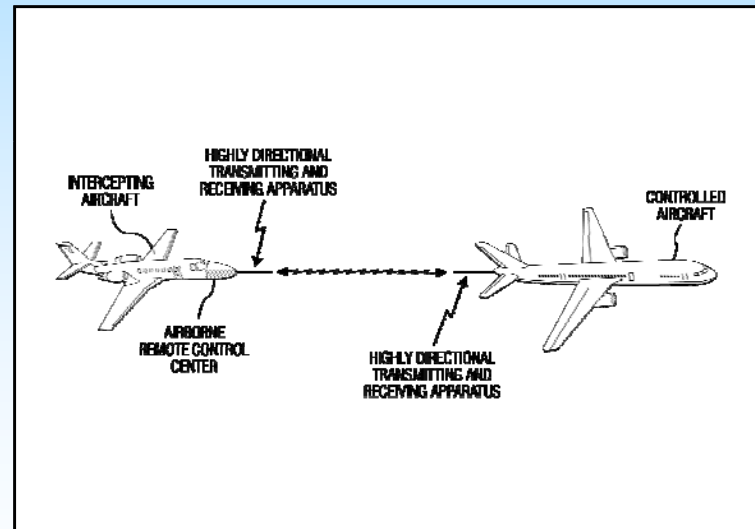
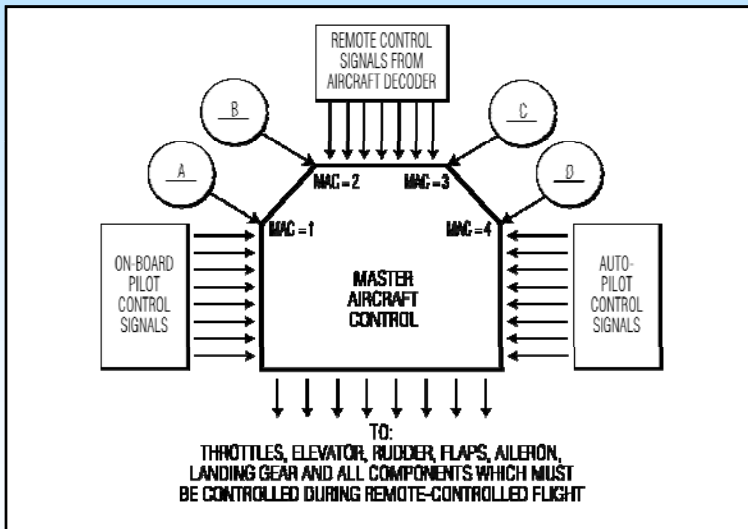
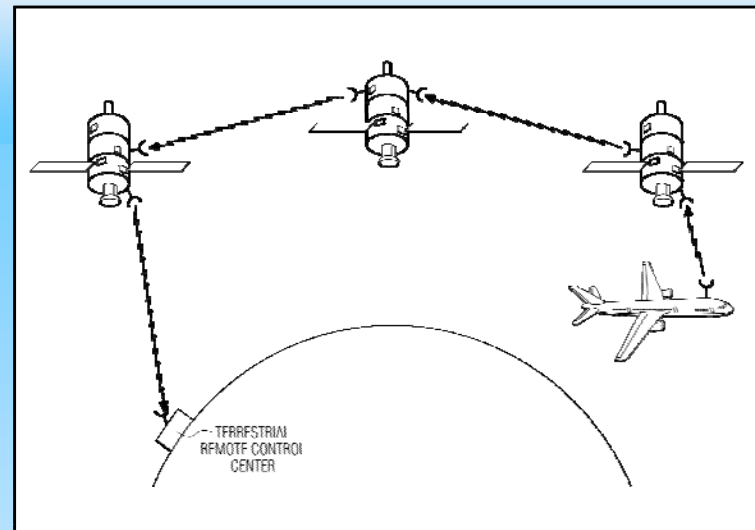
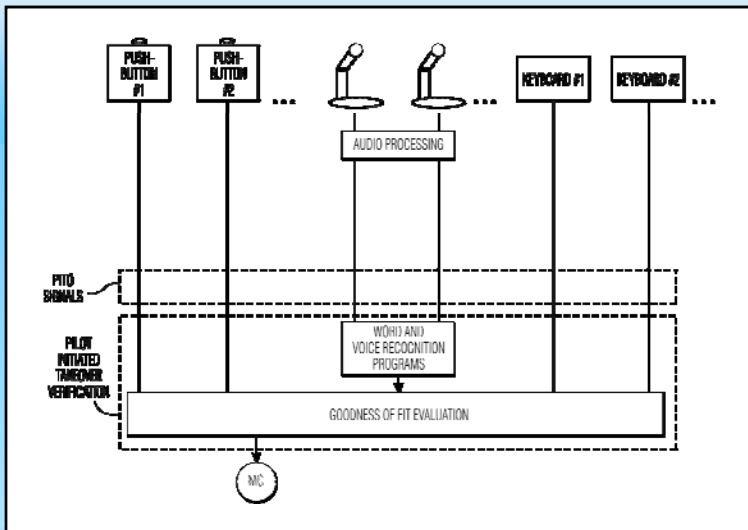


# Impaired Pilot Detection

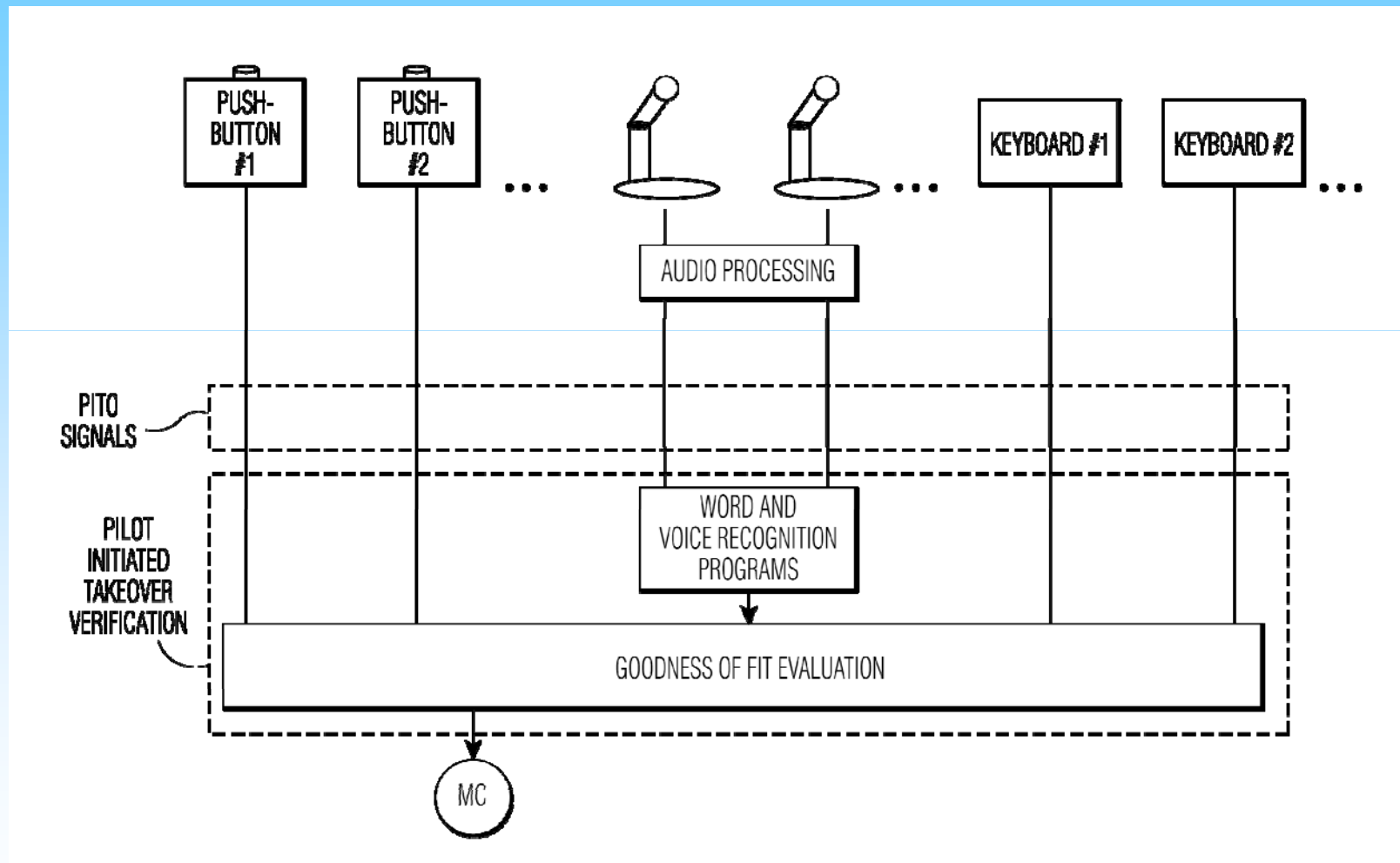


# Remote Control: Core Concept

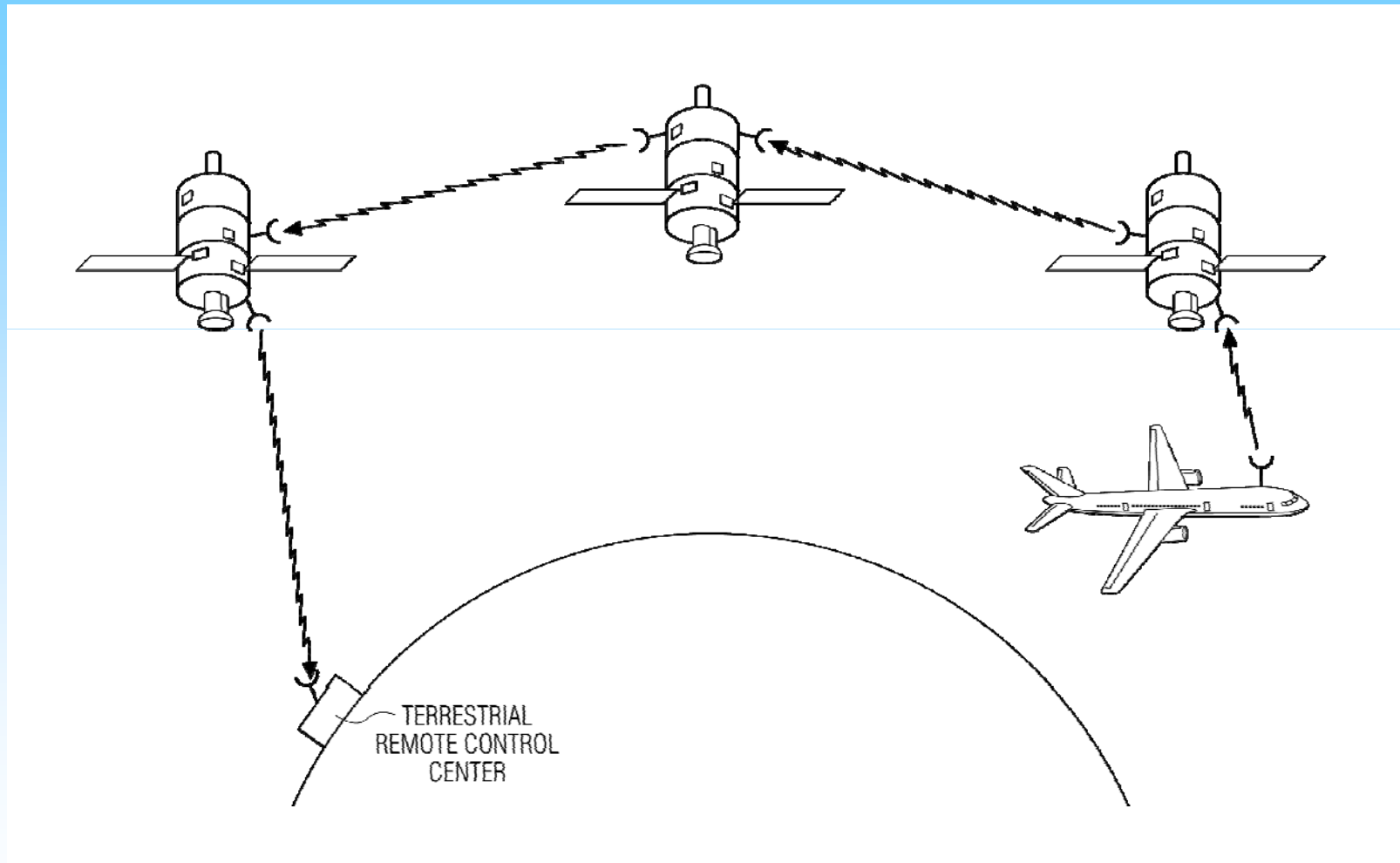
- Thwarting of aircraft hijack attempt by:
  - taking control of the aircraft away from the on-board pilot, and
- Giving control to alternate pilot, i.e. the autopilot and/or
  - human pilot aboard local interceptor aircraft, or
  - remotely situated human pilot
- The off-aircraft human pilot lands the hijacked aircraft.



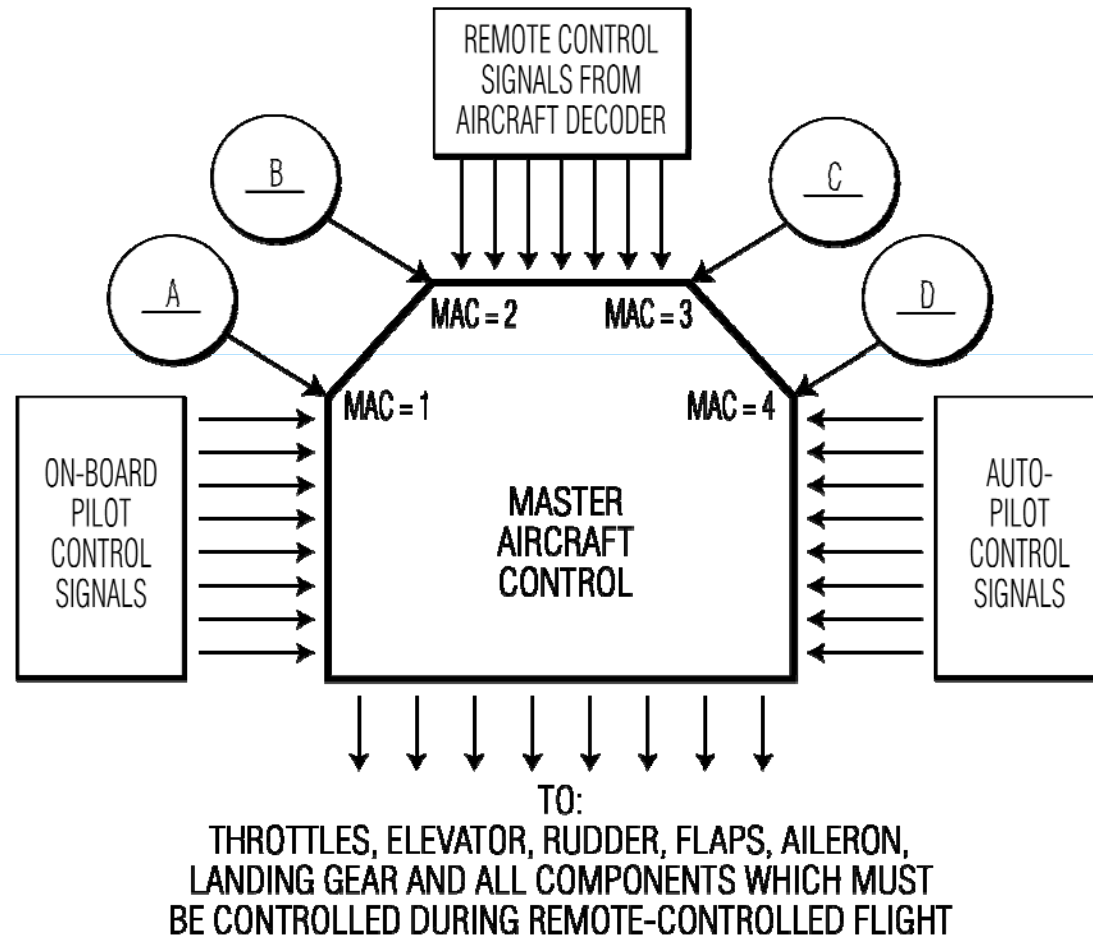
# Pilot-Initiated Takeover



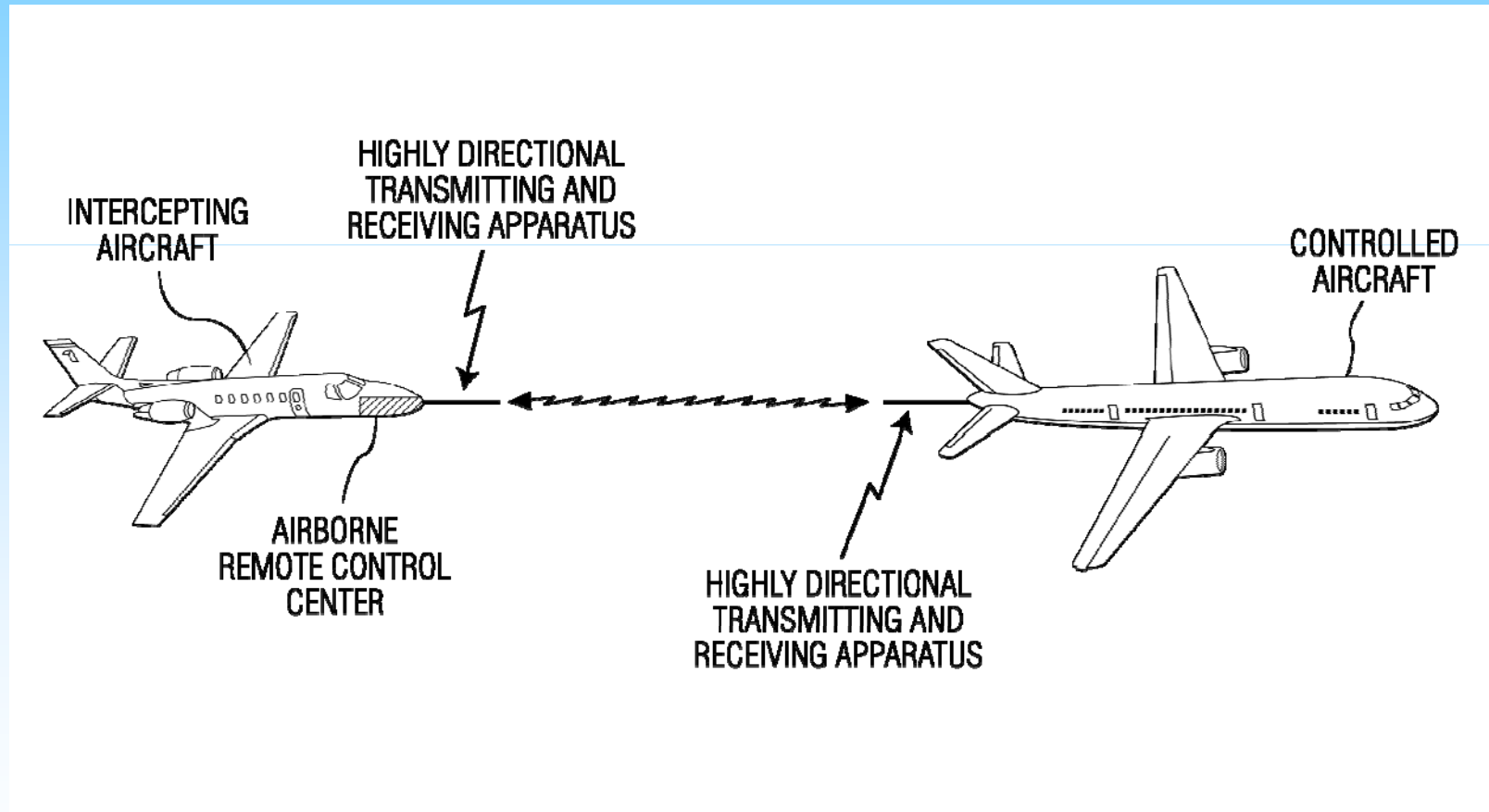
# PIT0 Signal Relayed to Control Center



# Master Aircraft Control



# Interceptor Aircraft-Based Pilot Flies Hijacked Aircraft

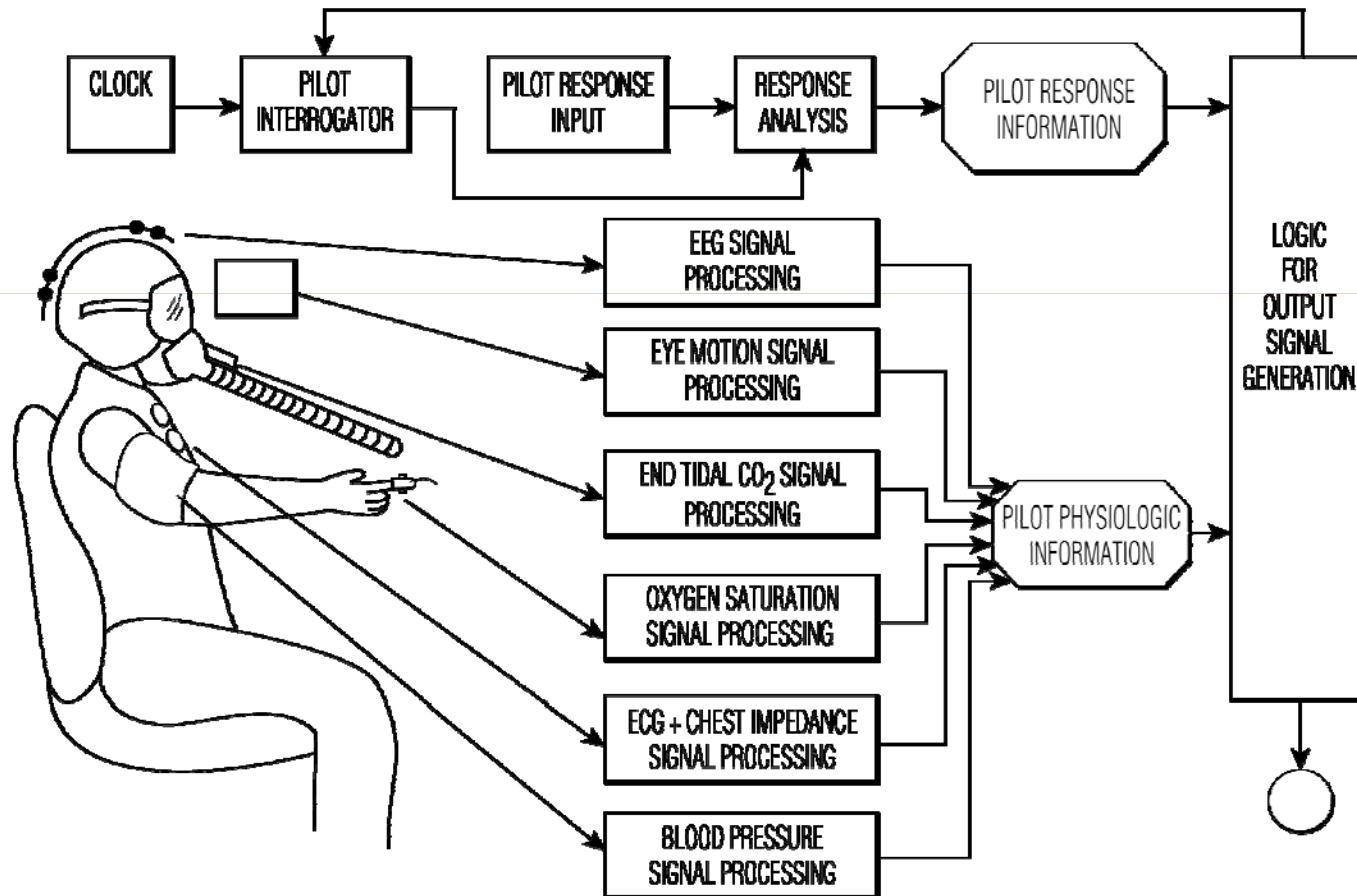


# Hijacking Neutralization



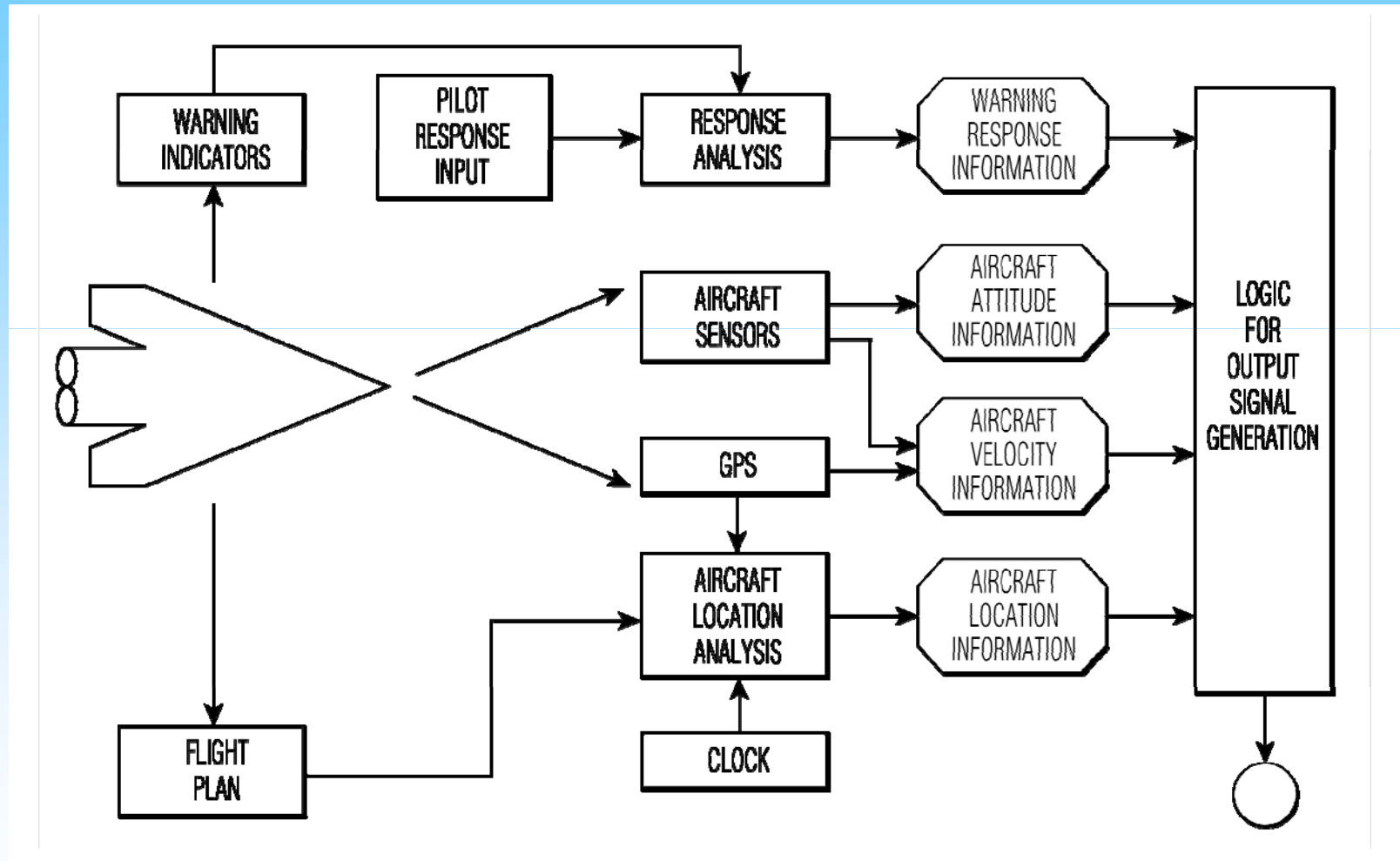
# Impaired Pilot Detection

## PHYSIOLOGIC ASSESSMENT



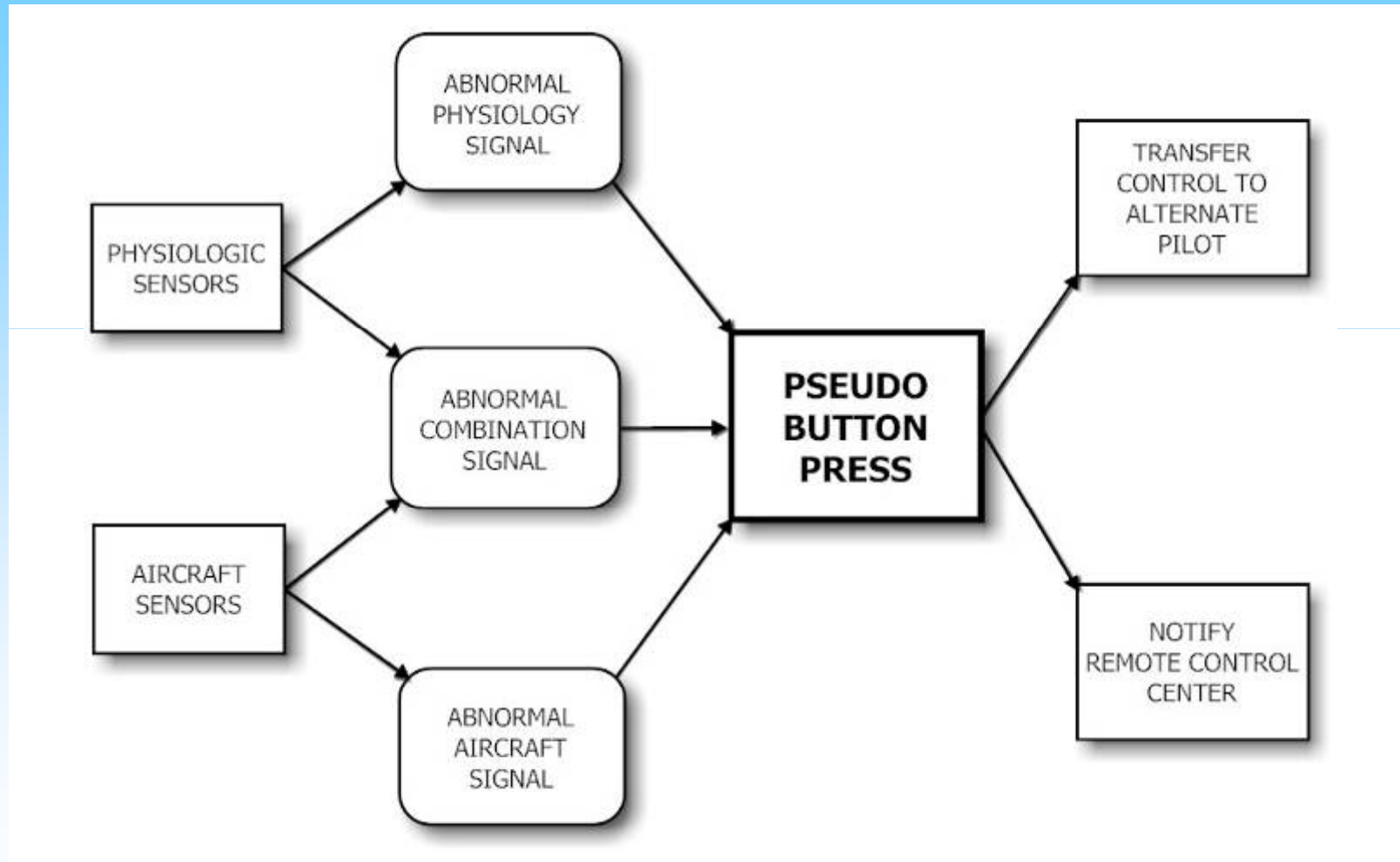
# Impaired Pilot Detection

## AIRCRAFT ASSESSMENT

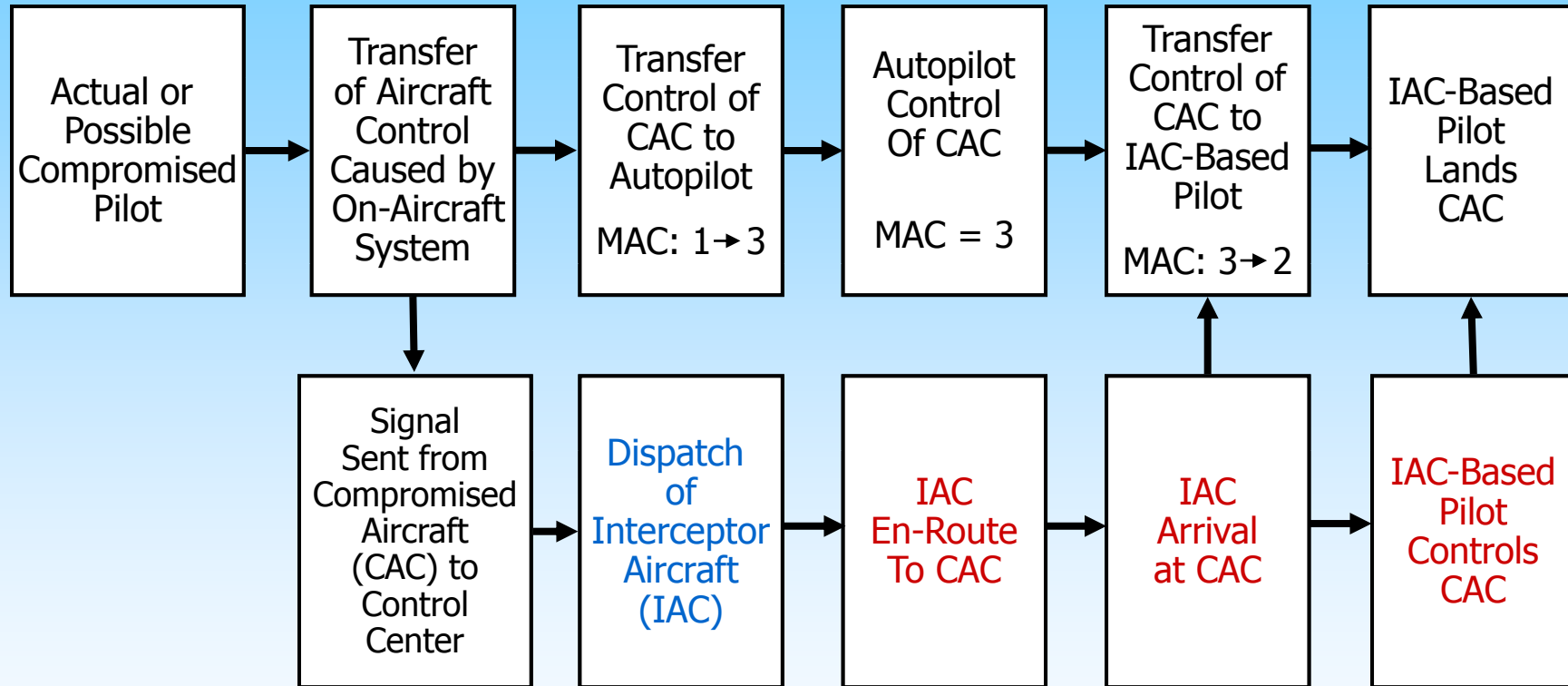


# Impaired Pilot Detection

## SYSTEM ACTIVATION



# Method 1B



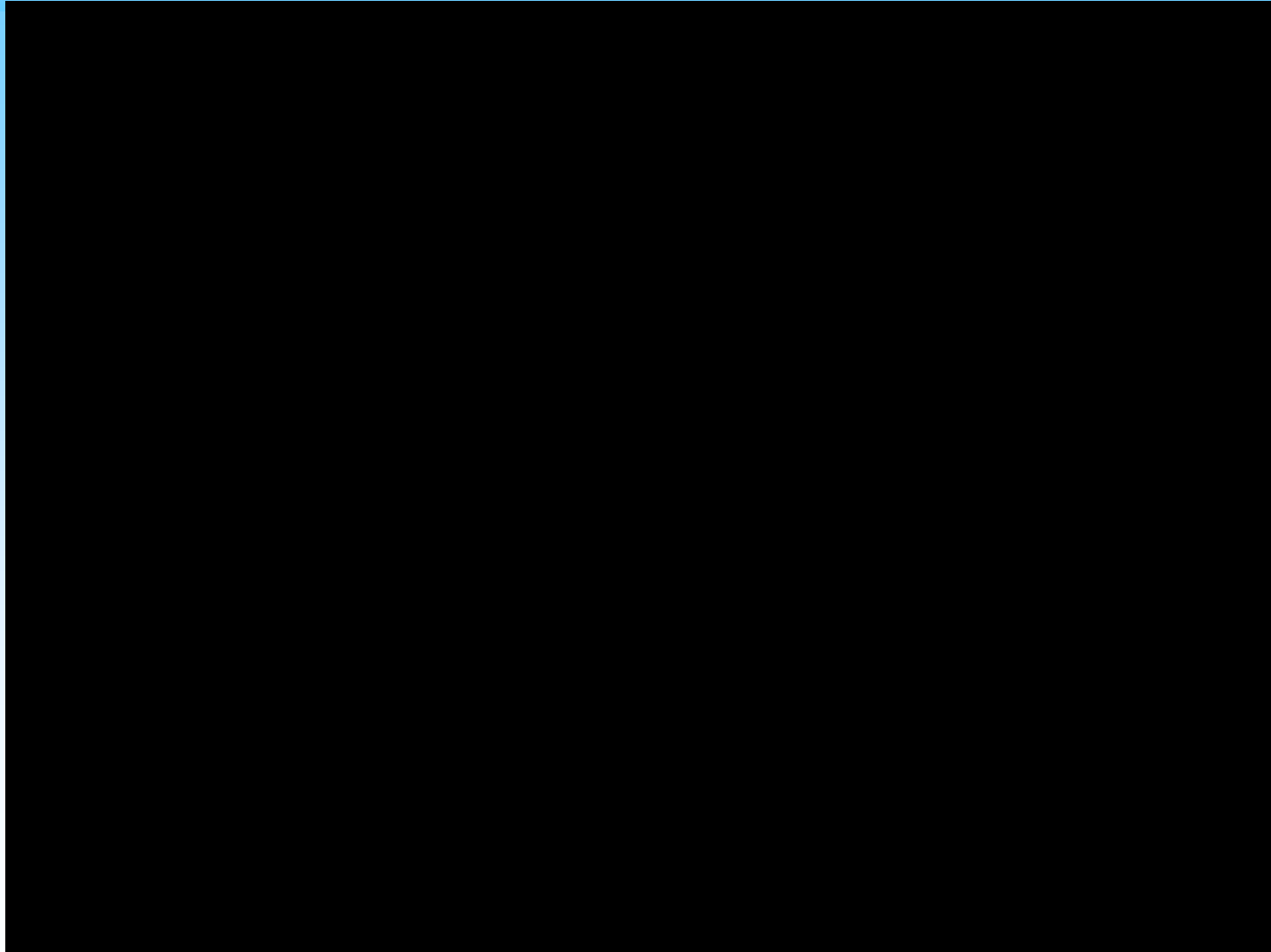
Black = CAC (Compromised Aircraft) Blue = RCC (Remote Control Center) Red = IAC (Interceptor Aircraft)

# Sample Takeover Scenario

TRIGGER = ABNORMAL PILOT PHYSIOLOGY

- Pilot injury
- Pilot bradycardia, i.e.
  - heart rate < 32 b.p.m.
  - Duration 25 seconds
- Pilot interrogation: No response
- Pseudo-button press
- Aircraft control transferred to AP/FMC

# Impaired Pilot Protection System



# Types of Takeover Triggers

- Abnormal Physiology
  - CARDIO-RESPIRATORY
  - COGNITIVE
  - BLENDED
- Sub-standard Pilot Control of Aircraft
- Abnormal Aircraft Position
- Combinations of Some or All of the Above

# Physiologic Triggers

SIMPLIFIED FORMAT

CARDIO-RESPIRATORY PARAMETERS

	Abnormal	Possibly Abnormal
Heart Rate	< 30 or > 200	< 35 or > 185
Systolic Blood Pressure	< 70	< 80
Respiratory Rate	< 6	< 8
Blood O <sub>2</sub> Saturation	< 80	< 85
Heart Rhythm	Ventricular Tachycardia	Supraventricular Tachycardia

# Physiologic Triggers

TIME DEPENDENT FORMAT  
ABNORMAL HEART RATE VALUES

Heart Rate	Duration
40-42 or > 190	60 seconds
35-39 or > 200	30 seconds
30-34 or > 220	15 seconds
< 30 or > 240	7 seconds

# Physiologic Triggers

TIME DEPENDENT FORMAT

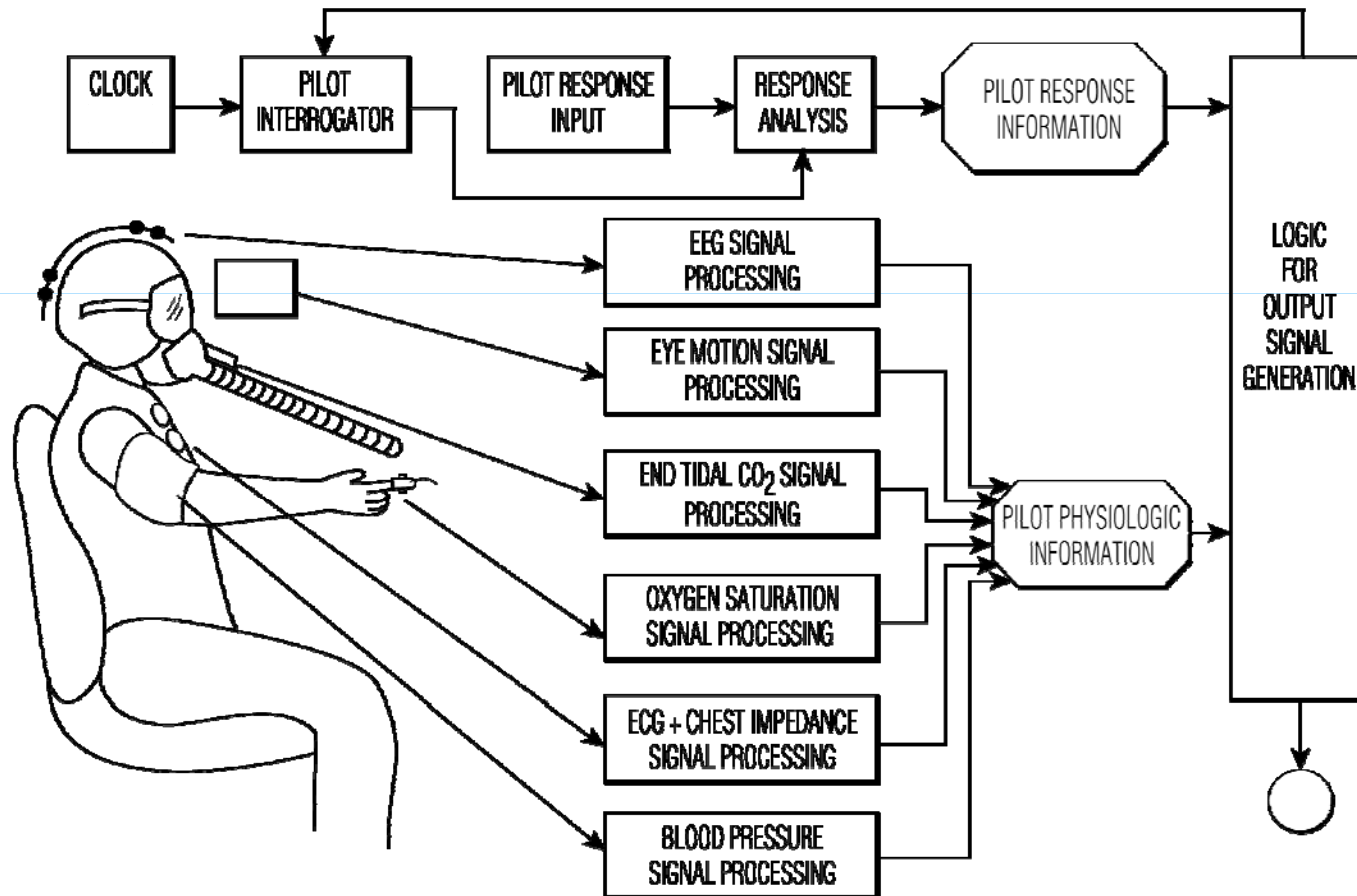
COMBINATIONS OF CARDIO-RESPIRATORY PARAMETERS

ABNORMAL VALUES ONLY

HR < 40 or SBP < 85	60 seconds
HR < 40 and SBP < 85	30 seconds
HR < 35 or SBP < 80	30 seconds
HR < 35 and SBP < 80	15 seconds
HR > 190 and either: - SBP < 80 or - Ventricular Tachycardia	12 seconds

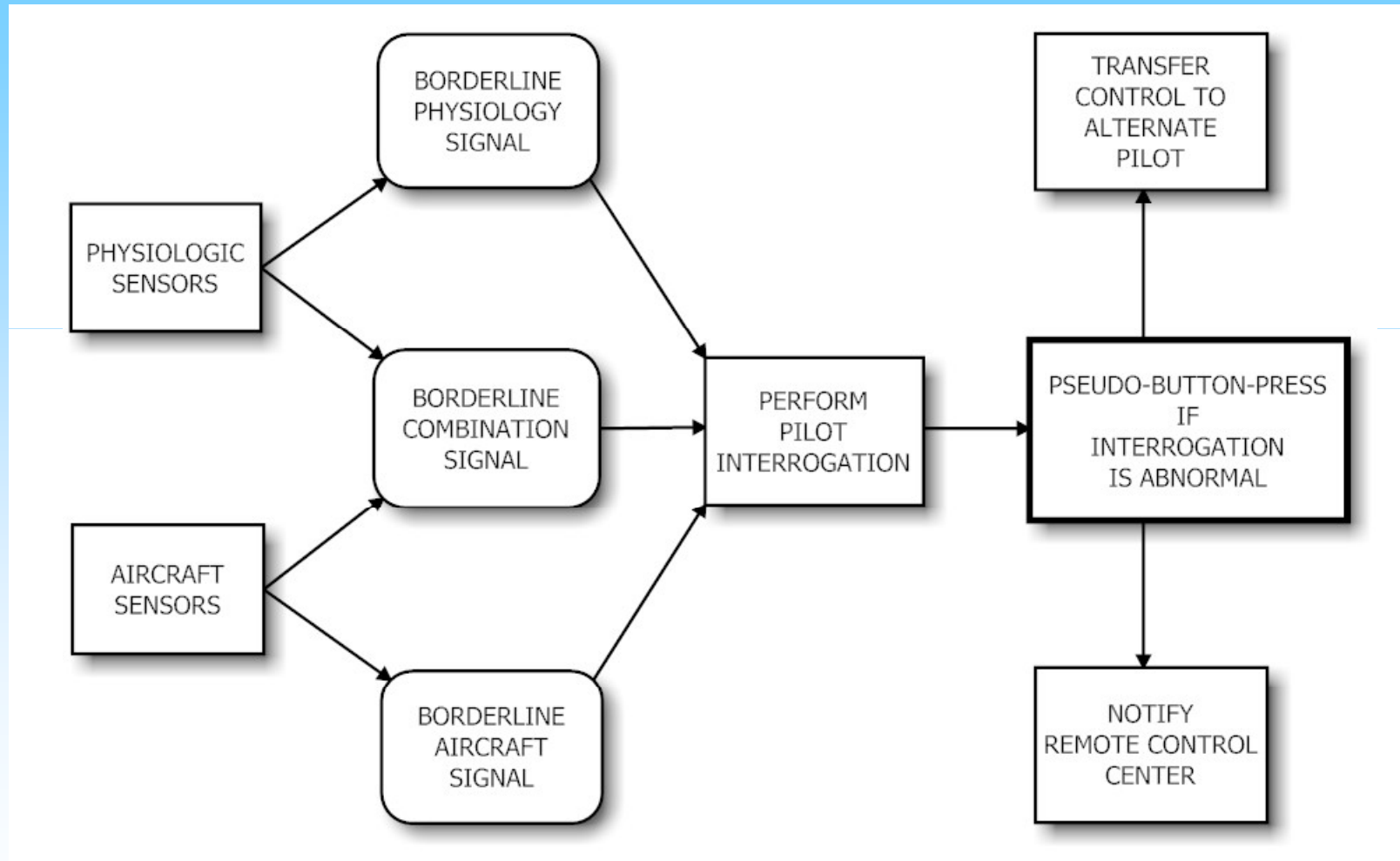
# Impaired Pilot Detection

## PHYSIOLOGIC ASSESSMENT



# Impaired Pilot Detection

## SYSTEM ACTIVATION



# Physiologic Triggers

## SIMPLIFIED FORMAT COGNITIVE PARAMETERS

	Definitely Abnormal	Possibly Abnormal
Timed Response - to test prompt - to warning indicator	> 7 sec.	4 – 7 sec.
Quantitative Task	Incorrect or No Response	Nearly Correct
Visual Task	Incorrect or No response	Nearly Correct
Eyelid Position	Closed	Intermittent Closed
Electroencephalogram (EEG) Rhythm	Non-Beta Rhythm	Intermittent non-beta rhythm

# Combinations of Cognitive Parameters

	Definitely Abnormal	Possibly Abnormal
Timed Response	> 7 sec.	4 – 7 sec.
Quantitative Task	Incorrect or No Response	Nearly Correct
Visual Task	Incorrect or No response	Nearly Correct
Eyelid Position	Closed	Intermittent Closed
EEG Rhythm	Persistent non- $\beta$	Intermittent non- $\beta$

## TAKEOVER TRIGGERED BY:

- Any definitely abnormal cognitive parameter
- Intermittent non- $\beta$  EEG rhythm and any other possibly abnormal cognitive parameter
- Any combination of three possibly abnormal parameters

MANY OTHER TRIGGERING FORMATS ARE POSSIBLE

# Combinations of Cardio-respiratory and Cognitive Parameters

CARDIO-RESPIRATORY	Abnormal	Possibly Abnormal
Heart Rate	< 30 or > 200	< 35 or > 185
Systolic Blood Pressure	< 70	< 80
Respiratory Rate	< 6	< 8
Blood O2 Saturation	< 80	< 85
Heart Rhythm	V. Tach.	S.V. Tach.

COGNITIVE	Definitely Abnormal	Possibly Abnormal
Timed Response	> 7 sec.	4 – 7 sec.
Quantitative Task	Incorrect / No Response	Nearly Correct
Visual Task	Incorrect / No response	Nearly Correct
Eyelid Position	Closed	Intermittent Closed
EEG Rhythm	Persistent non-β	Intermittent non-β

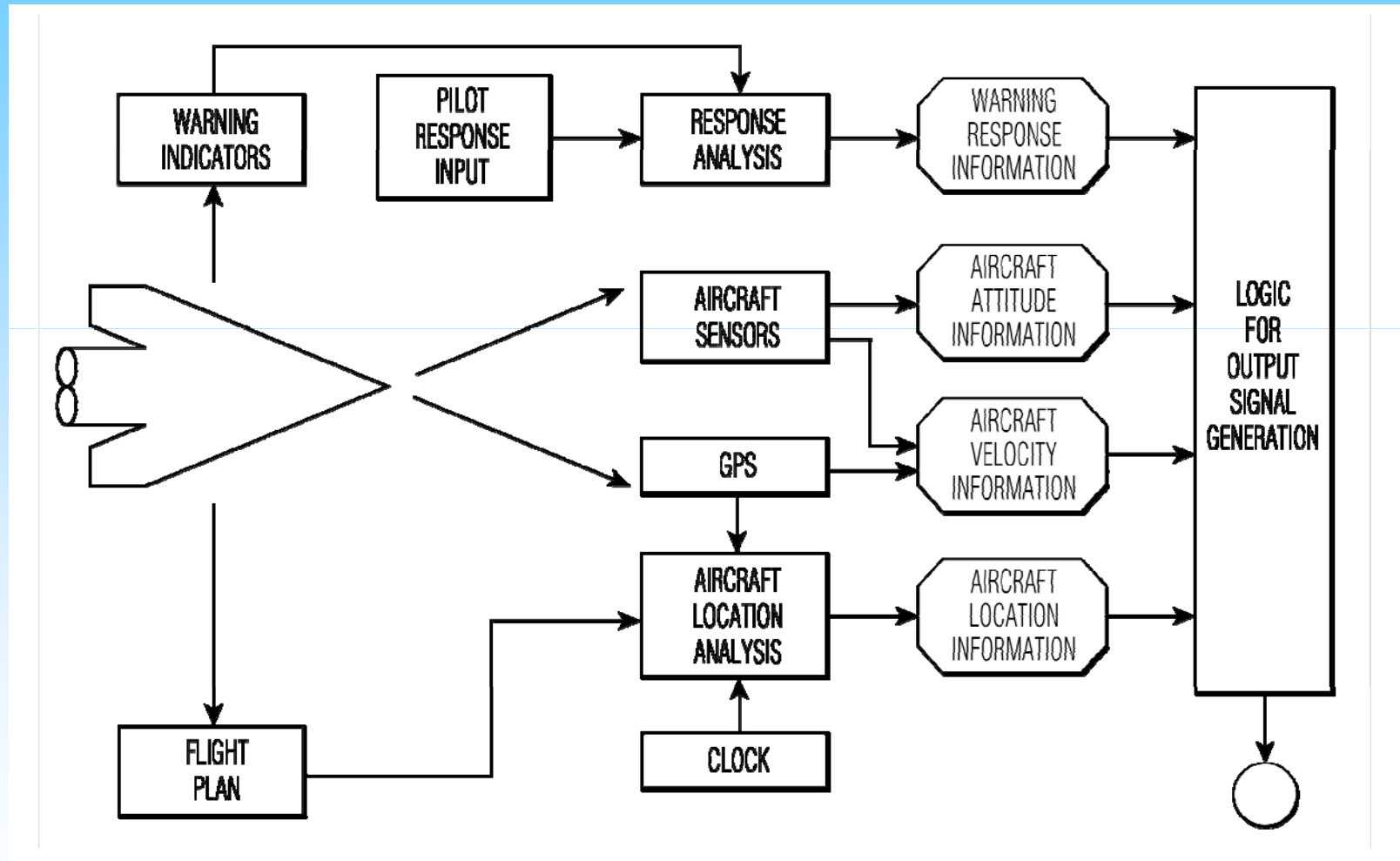
## TAKEOVER TRIGGERED BY:

- Any definitely abnormal cognitive parameter
- Any two definitely abnormal cardiorespiratory (CR) parameters
- Any definitely abnormal CR parameter and a possibly abnormal cognitive parameter
- Intermittent non-β EEG rhythm and any abnormal CR parameter
- Ventricular Tachycardia and any possibly abnormal cognitive parameter
- Any combination of three possibly abnormal parameters

MANY OTHER TRIGGERING FORMATS ARE POSSIBLE

# Impaired Pilot Detection

## AIRCRAFT ASSESSMENT



# Parameters of Abnormal Aircraft Motion

- Abnormal velocity
- Abnormal aircraft attitude
- Abnormal rate of change of attitude
- Abnormal position of any control surface
- Abnormal aircraft location

## EXAMPLES OF AIRCRAFT TAKEOVER SCENARIOS:

- Any major abnormality
- Any two minor abnormalities

# Combinations of Aircraft Motion, Cognitive and Cardio-Respiratory Parameters

## EXAMPLES OF MAJOR ABNORMALITIES

- Non Beta EEG
- Non Response to Warning Indicators
- Highly Inappropriate Aircraft Location
- Highly Inappropriate Aircraft Motion
- Both Heart Rate < 32 and Systolic BP <75 for > 25 Seconds

## EXAMPLES OF MODERATE ABNORMALITIES

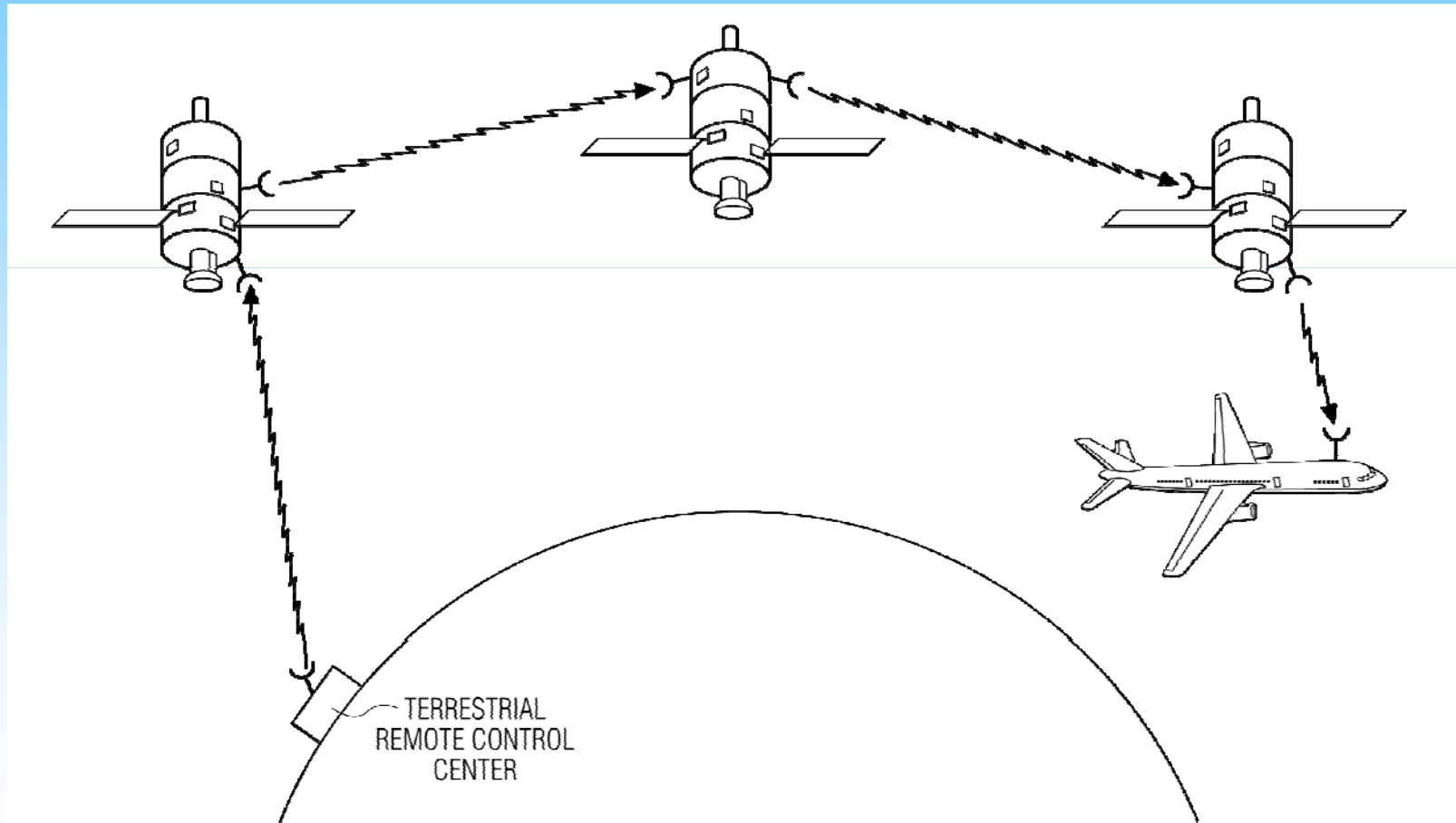
- Ventricular Tachycardia
- Sub-Optimal Response to Warning Indicators
- Moderately Inappropriate Aircraft Location
- Moderately Inappropriate Aircraft Motion
- Either Heart Rate < 36 or Systolic BP < 80 for 40 Seconds

## TAKEOVER SCENARIOS

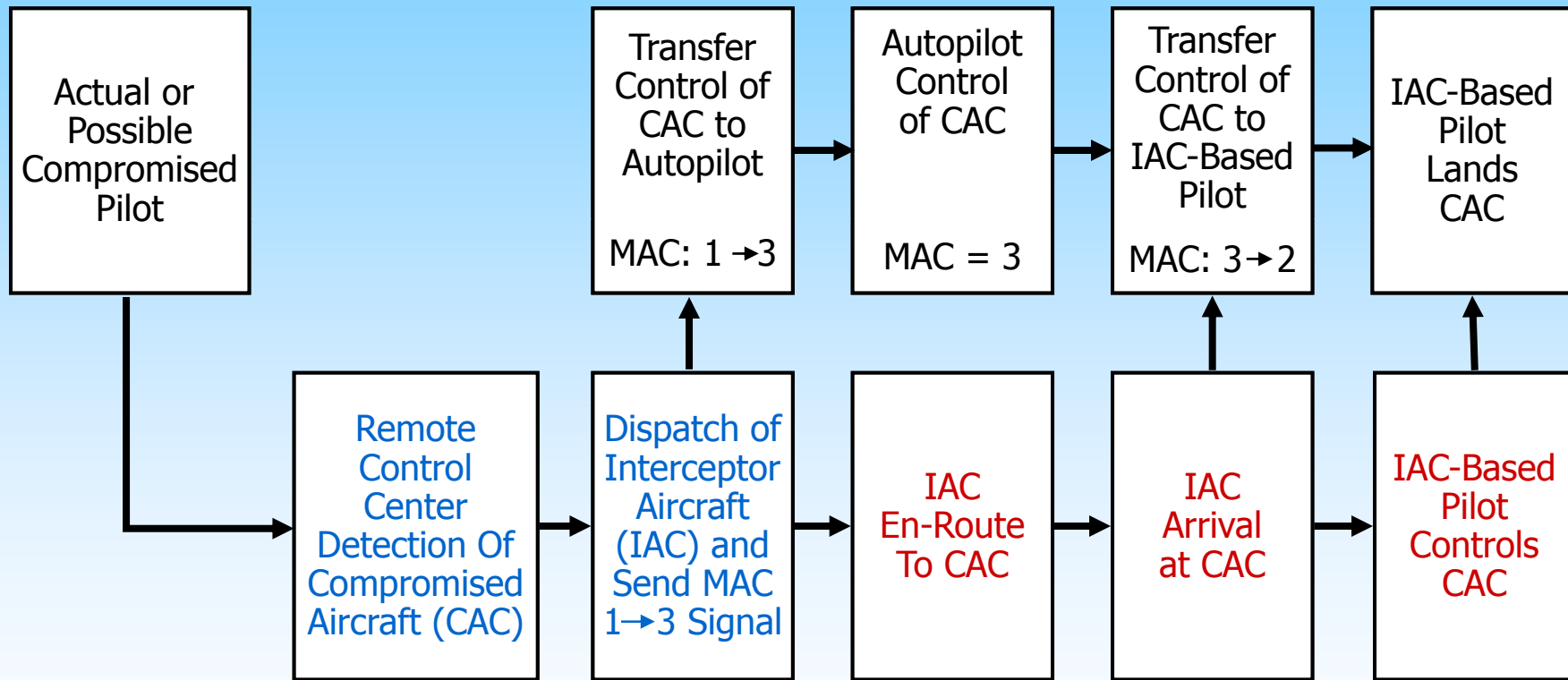
- Any major abnormality
- 2 or more moderate abnormalities
- 3-4 or more less critical abnormalities (NOT LISTED ABOVE)

MANY OTHER TAKEOVER FORMATS ARE POSSIBLE

# Takeover Signal Sent from Terrestrial Control Center



# Method 2B



# Classification of Takeover Signal Origination and Post T.O. Action

<b>TAKEOVER FORMAT</b>	<b>INITIAL AUTOPILOT</b>	<b>INITIAL REMOTE PILOT</b>
On-Aircraft	Method 1B	Method 1A
Off-Aircraft, Distant	Method 2B	Method 2A
Off-Aircraft, Local	Method 3B	Method 3A

# Options for Return of Control (ROC)

- No ROC whatsoever
- ROC only by Remote Control Center (RCC)
- ROC if both RCC and Sensors agree
  - Hysteresis pre ROC – Sensor readings must return to definitively normal values (not borderline ones)
  - Probation post ROC – Lower threshold for re-triggering of takeover post ROC

# Use of the System for Detection and Management of Impaired UAV/ UUV/ UGV Operator

- Includes vehicle position and motion sensors
- Includes evaluation of operator response to warning lights and intermittent system test prompts
- May include evaluation of operator eye motion and head position
- May not include ECG, EEG, SBP and respiratory monitoring

# Systems for Controlling Compromised Aircraft

- Contact: 914-949-3645  
White Plains, New York



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- [KMilde@MMTechUSA.com](mailto:KMilde@MMTechUSA.com)
- [AviationSafety@optonline.net](mailto:AviationSafety@optonline.net)

# Method 1A

