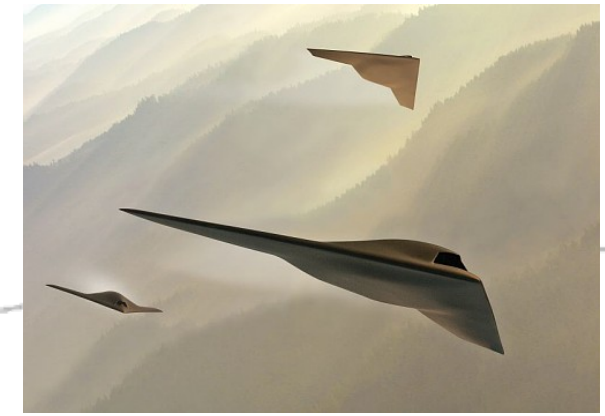
# *From Combat Aircrafts to Unmanned Combat Air Systems*



## *Autonomy and Control Segment challenges*

DASSAULT AVIATION

# Plan

*Main Drivers for UCAV emergence*

*Similarities and differences (from Operator perspectives)*

*Challenges*

*Design process challenges*

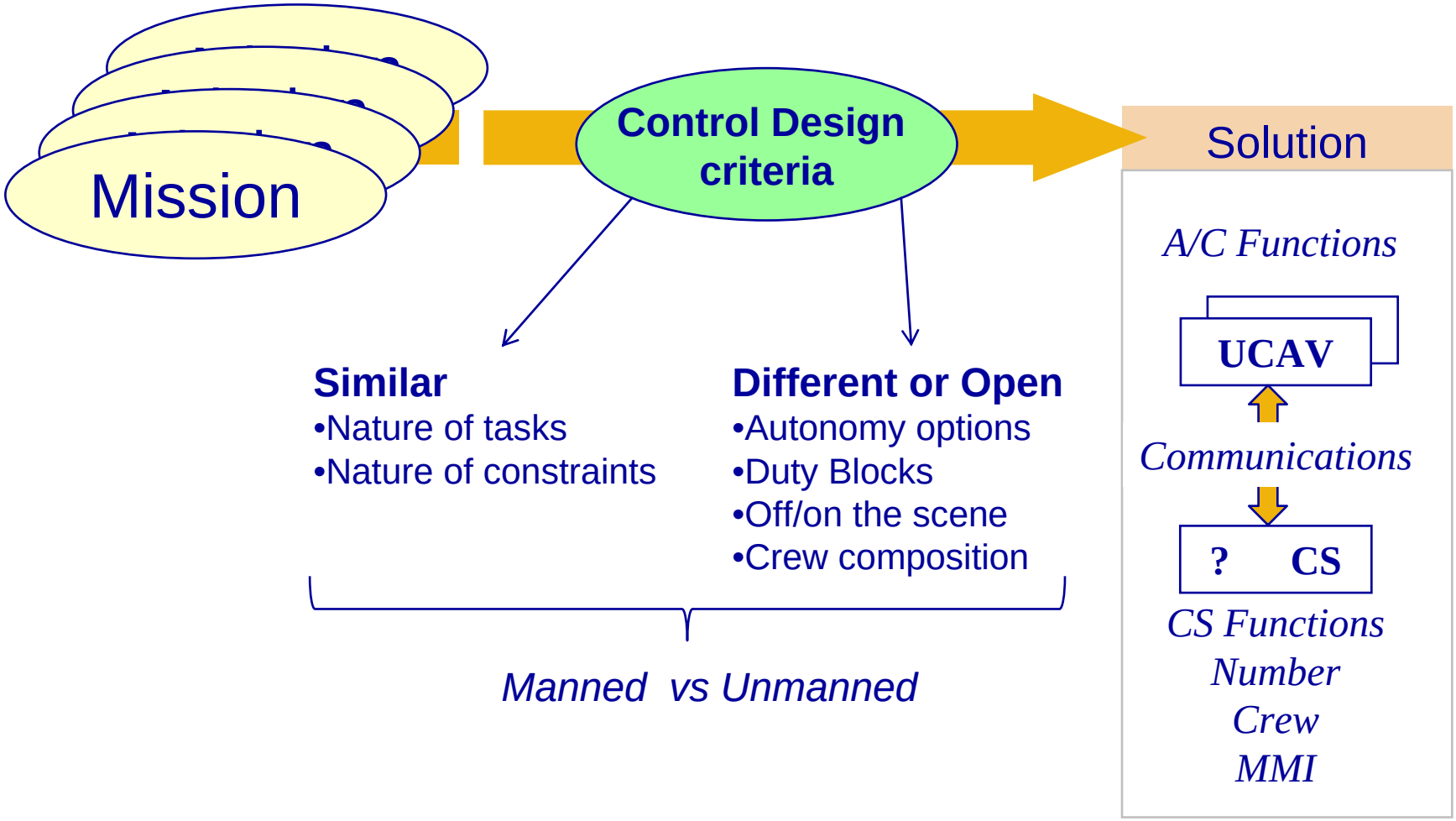
# *Why UCAVs?*

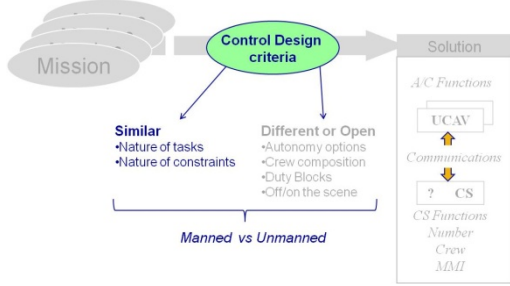
- *Operation*
  - Dull
  - Dirty
  - Dangerous
- *Design relaxed from presence of human*
  - Sorties Duration
- *Operating Cost savings potential*
  - Reduced Flight hours
  - Reduced personnel (snow ball effect on fleet size)

# Our objectives

- *Long Term : Definition of UCAV control configuration*
  - Autonomy and associated capabilities
  - Projection on UCAV system components
    - Air vehicle(s)
    - Control Segment
  - Role(s) and number of operators
- *Short Term :*
  - Process maturation
  - V&V issues
  - Capability developments

# Design challenges
# Architecture






# Nature of system tasks

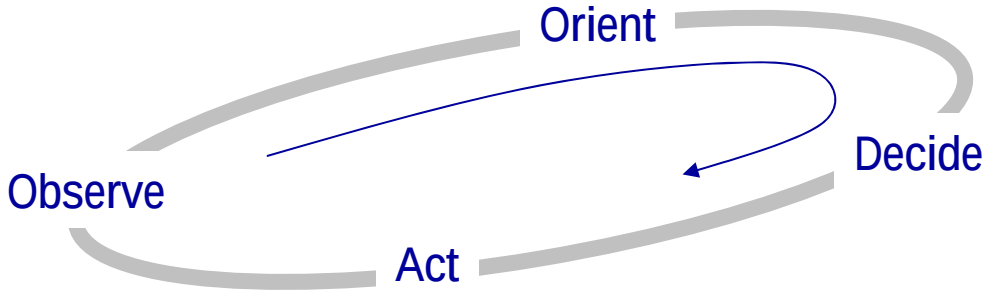
## *Cognitive Functions :*

Observe,

Orient,

Decide,

Act



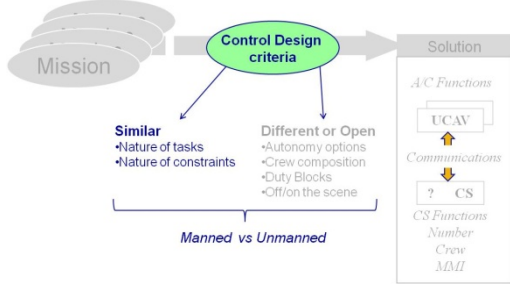

## *Applicable to all tasks type and levels*

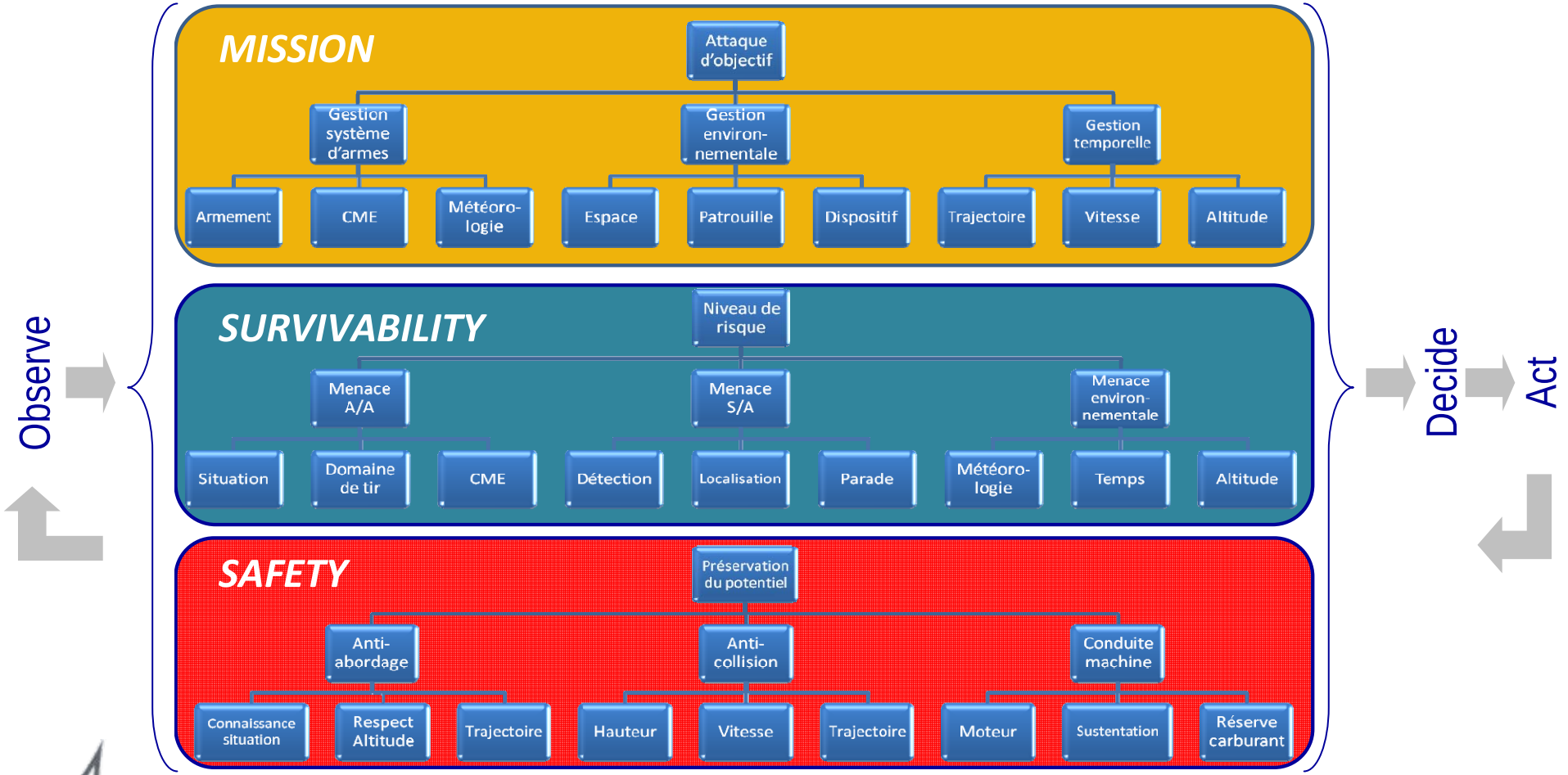
Domains : Mission, Survivability, Safety (MSS)

What : Package control, Air Vehicle, control Sub system control

# Nature of system tasks

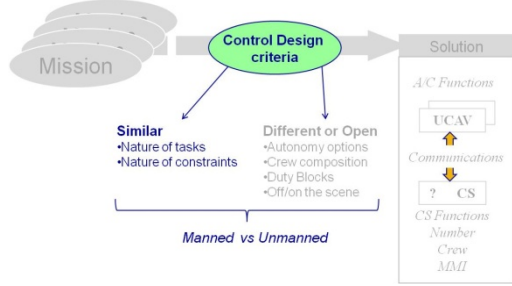
# Illustration

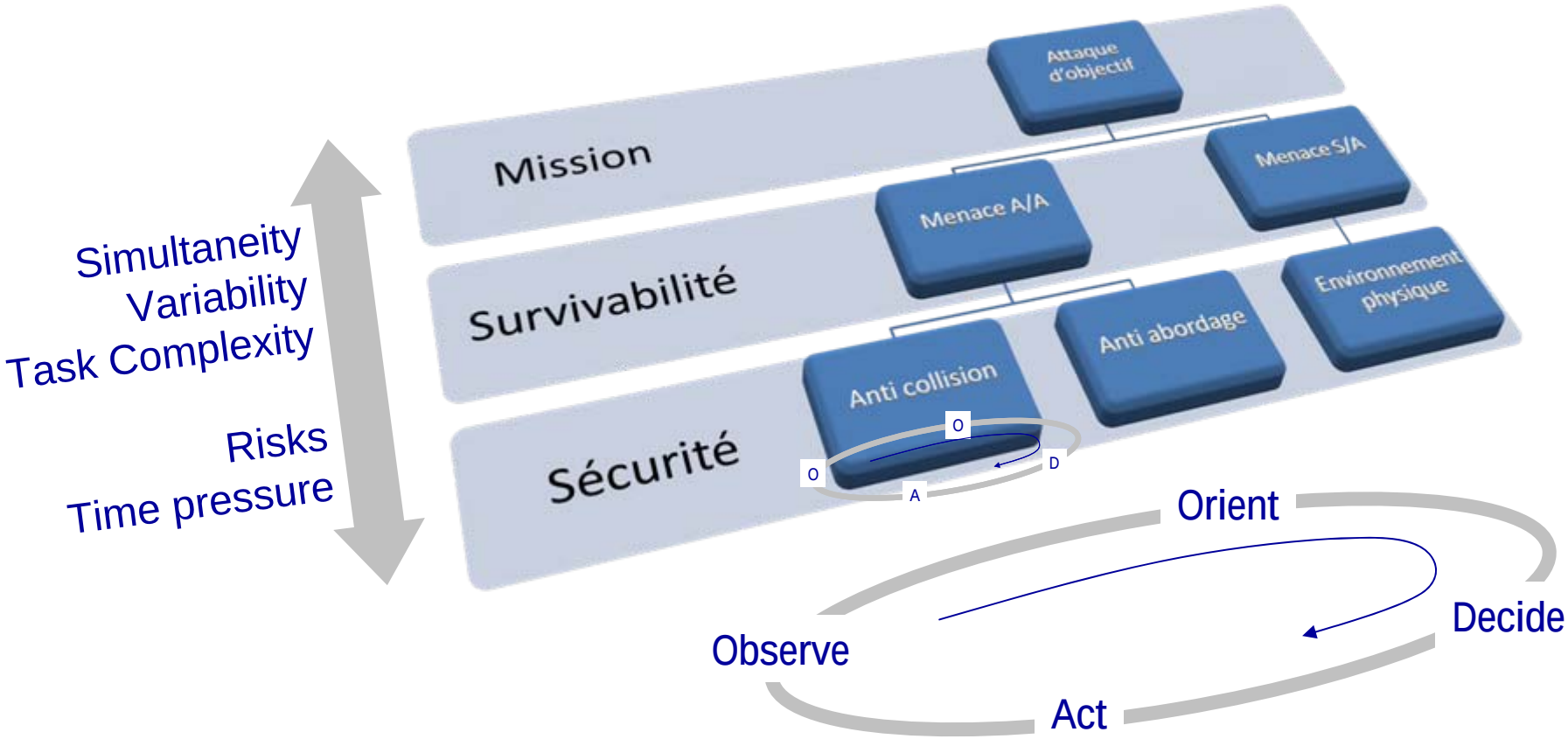


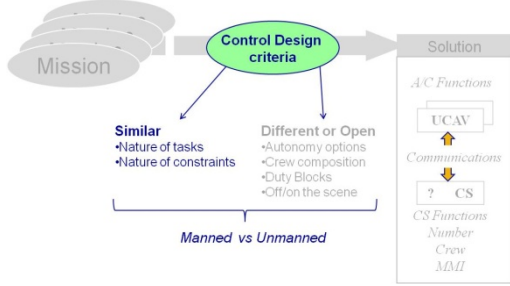



# *Nature of system tasks*

# *Control Complexity*



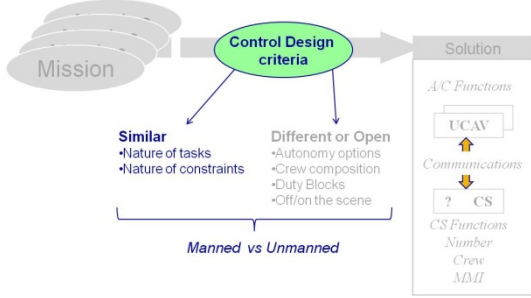



## *Nature of system tasks*

# *Tasks drivers*

- *Mission complexity and varaibility*
  - C2 interactions, Coordination, Cooperation
  - Time pressure
  - Level of knowledge on environment
  - ROEs, Tactics
- *Environment complexity and variability*
  - Targets : Nature, Number, collateral, decoy
  - Threats, EM environment
  - Terrain, Constructions…
  - Weather, Day/night

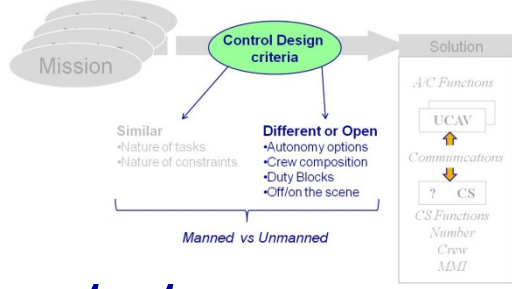
# Nature of constraints




- *Responsability*
  - VID / PID (Visual Positive Identification)
    - Features and Accuracy sensors
    - Trans/receipt of data (imagery)
    - Dealing of engagement clearance (process)
    - Decision/Action loop
  - CDE (Collateral Damage Effect)
    - Detection/Loc of civilian/friendly activity or unknown
    - Weapponering, Effect Based Operations
    - BDA, Re Atq
    - NCW, Illu, ISR, Wpny
- *Safety*
  - (Combat) airspace integration (see and avoid)
  - Platform and environment integrity

## *Nature of system tasks*

# *Autonomy options*




- *Definition of autonomy : various scales up to ten levels*
- *Application Field up to 4 (OODA)*
- *Applicable to all tasks type & levels : 3 domains (MissionSurvivability, Safety), at least 3 levels (package, vehicle, subsystems)*
- *Multiple missions or CONOPS*

  ⇒Analytical approach might prove not be practicable (# of combinations)

  ⇒Limited to a substitution approach (no augmented capability, no cooperative approach, intricated tasks)

Example of Autonomy/OODA Projection (Proud et al.)

| Level | Observe | Orient | Decide | Act |
|---|---|---|---|---|
| 8 | The computer gathers, filters, and prioritizes data without displaying any information to the human. | The computer predicts, interprets, and integrates data into a result which is not displayed to the human. | The computer performs ranking tasks. The computer performs final ranking, but does not display results to the human. | Computer executes automatically and does not allow any human interaction. |
| 7 | The computer gathers, filters, and prioritizes data without displaying any information to the human. Though, a "program functioning" flag is displayed. | The computer anlayzes, predicts, interprets, and integrates data into a result which is only displayed to the human if result fits programmed context (context dependant summaries). | The computer performs ranking tasks. The computer performs final ranking and displays a reduced set of ranked options without displaying "why" decisions were made to the human. | Computer executes automatically and only informs the human if required by context. It allows for override ability after execution. Human is shadow for contingencies. |
| 6 | The computer gathers, filters, and prioritizes information displayed to the human. | The computer overlays predictions with analysis and interprets the data. The human is shown all results. | The computer performs ranking tasks and displays a reduced set of ranked options while displaying "why" decisions were made to the human. | Computer executes automatically, informs the human, and allows for override ability after execution. Human is shadow for contingencies. |
| 5 | The computer is responsible for gathering the information for the human, but it only displays non-prioritized, filtered information. | The computer overlays predictions with analysis and interprets the data. The human shadows the interpretation for contingencies. | The computer performs ranking tasks. All results, including "why" decisions were made, are displayed to the human. | Computer allows the human a context-dependant restricted time to veto before execution. Human shadows for contingencies. |
| 4 | The computer is responsible for gathering the information for the human and for displaying all information, but it highlights the non-prioritized, relevant information for the user. | The computer analyzes the data and makes predictions, though the human is responsible for interpretation of the data. | Both human and computer perform ranking tasks, the results from the computer are considered prime. | Computer allows the human a pre-programmed restricted time to veto before execution. Human shadows for contingencies. |
| 3 | The computer is responsible for gathering and displaying unfiltered, unprioritized information for the human. The human still is the prime monitor for all information. | Computer is the prime source of analysis and predictions, with human shadow for contingencies. The human is responsible for interpretation of the data. | Both human and computer perform ranking tasks, the results from the human are considered prime. | Computer executes decision after human approval. Human shadows for contingencies. |
| 2 | Human is the prime source for gathering and monitoring all data, with computer shadow for emergencies. | Human is the prime source of analysis and predictions, with computer shadow for contingencies. The human is responsible for interpretation of the data. | The human performs all ranking tasks, but the computer can be used as a tool for assistance. | Human is the prime source of execution, with computer shadow for contingencies. |
| 1 | Human is the only source for gathering and monitoring (defined as filtering, prioritizing and understanding) all data. | Human is responsible for analyzing all data, making predictions, and interpretation of the data. | The computer does not assist in or perform ranking tasks. Human must do it all. | Human alone can execute decision. |

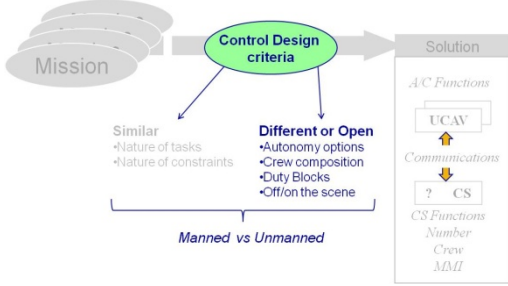
## *Design challenges*

# *Automation & Autonomy*

- *Automation to relax or substitute to operator tasks (workload, feasibility…); e.g :*
  - Flight control
  - Assisted Automatic Target Recognition
- *Automation might be mandatory*
  - e.g. to cope with loss of communications at least to guarantee a safe flight termination (this situation has to be regognised and the decision made by the system)
- *Autonomy functions to contribute to decision process*
  - Awareness
  - Field of solutions definition/exploration
  - Select actions
- *Autonomy and automation are both requested*

# *From combat A/C to UCAV*

# *Duty blocks*




## Constrained Duty Block

Duty block ~ Flight Duration

Max sortie duration

Continuous activity

One platform/one crew

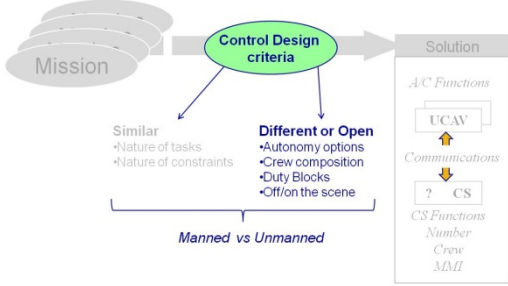
## Flexible Duty Block

Fragmented activity

Specialisation opportunity

Unlimited sortie duration

# *From combat A/C to UCAV*
# *On/Off the scene*

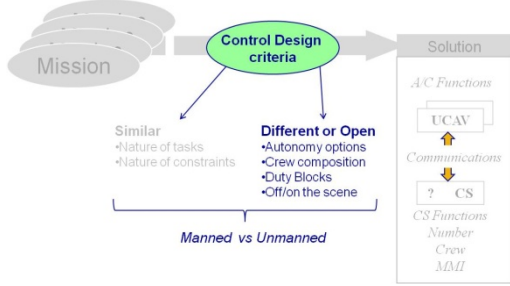



## On The scene

- Local SA, possibly augmented through NEC
- Local Multi source correlation by operator
- Exposed to risks (flight, threats)
- Involvement in local challenges
- Adapt to unpredicted/complex situations

## Off The scene

- Global SA, augmented through Local informations (sensors)
- Limited operator local source correlation (FOR, Vision, Scene analysisis)
- Limited risk perception
- Possible distanciation with theater (video game effect)




# *From combat A/C to UCAV*

# *Crew Composition*

## Crew

Max 2 : Pilot & possibly WSO

Multi role endorsment


## Crew

Max : Open but max number is a challenge (cost, training…)

Flexible/adaptable to mission complexity

Roles could be driven by mission needs

Possibility of new principles for operators role definition; e.g. :

- One crew for several platforms
- Specialisation

## *Design challenges*

# *Control segment*

## Role(s) & Number and of operators

*From*

- Single platform control and Sub Systems

*to*

- Package control
  - Coordination (TOT, Deconfliction), Cooperation (tasks performed by several systems)
  - Same systems vs heterogebeous systems

- Targeted Operator/UCAV ratio <Fighter crew ratio

- Keep Flexibility

- Cope with HF (Workload, Short cut capacity)

## CS challenges

# Single platform operation

(1) Fighter

How many operators for 1 UCAV?

UCAV

? CS

(1) CS

CS

UCAV

Fighter

UAV ISR

CS

Other Control segment options : e.g. fighter?

Flight controller

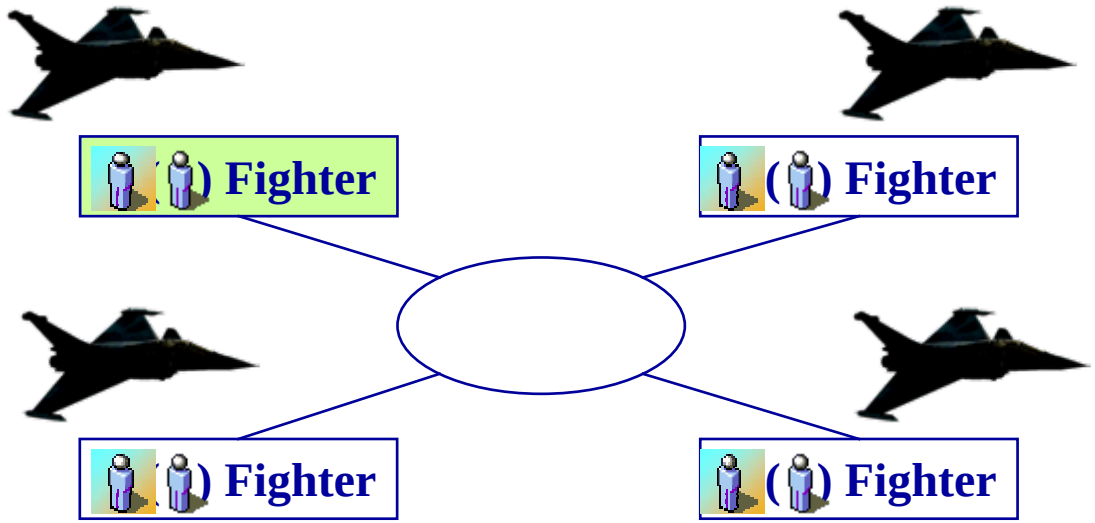
Mission controller

Systems operator

UCAV OB controller

## CS challenges

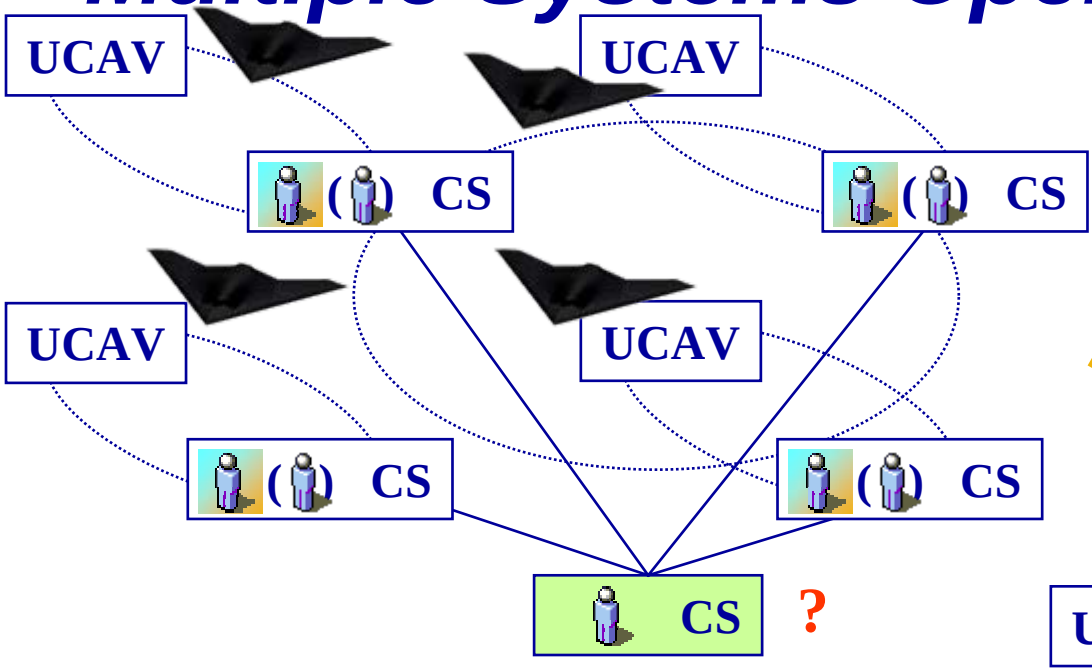
# Multiple System operation




Flight controller
Mission controller
Systems operator

## CS challenges

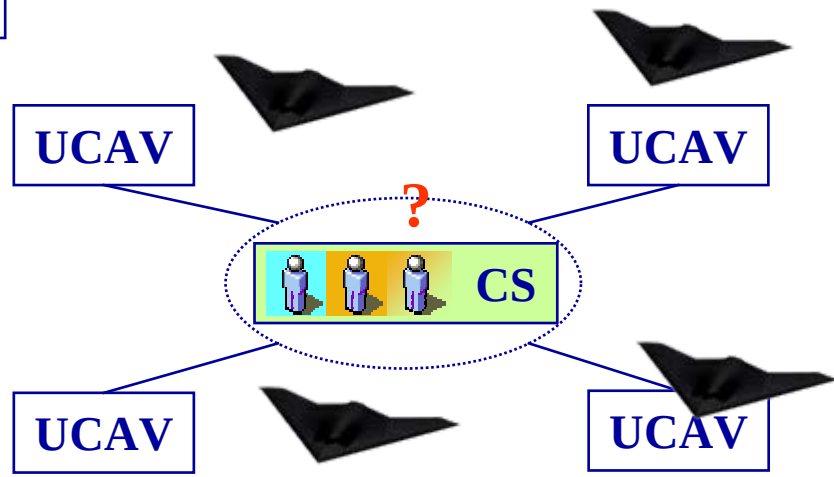
# Multiple Systems Operation




**Cooperation between operators?**
**Mission commander?**
**Remote Cooperation**


Flight controller
Mission controller
Systems operator

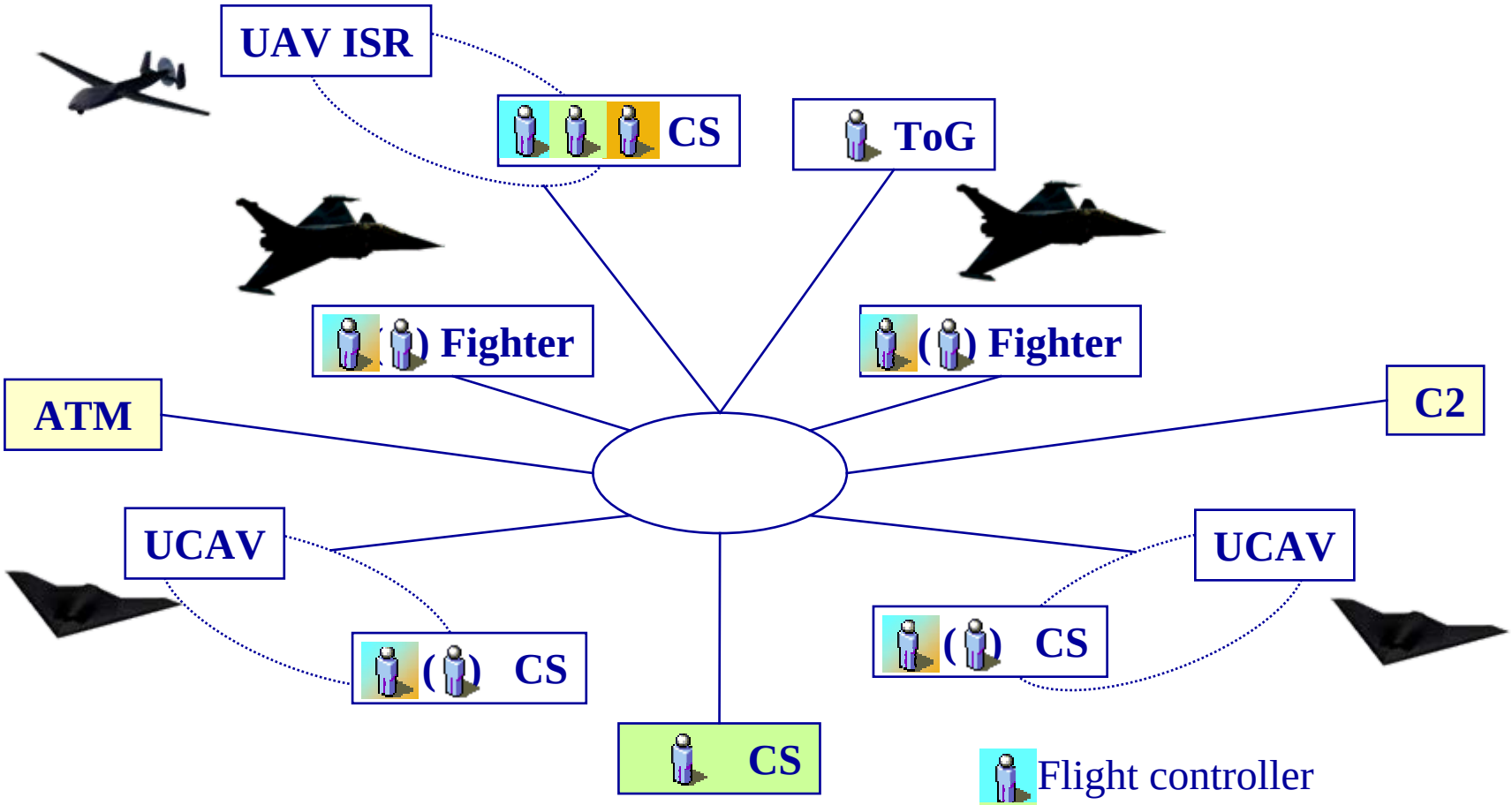
***UCAV***




**Decrease of operator number?**
**Different Roles?**
**Shared workspace?**

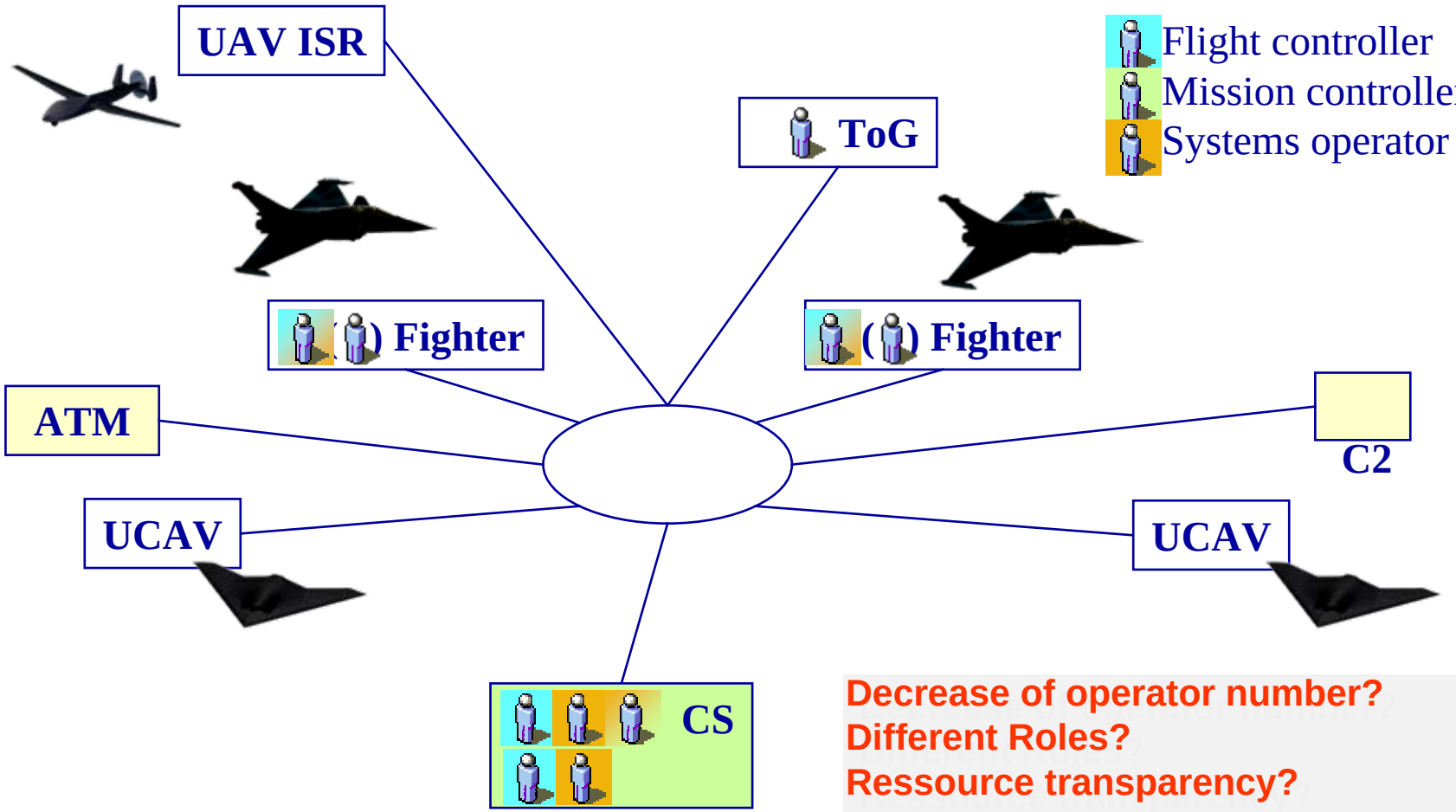
## CS challenges

# Mixed operation



## CS challenges

# Mixed operation




**Decrease of operator number?**
**Different Roles?**
**Ressource transparency?**
**Shared workspace?**

## *CS challenges*

# *System Properties*

- *Behavior friendly*
  - Enable Anticipation & prediction
  - Understand & cooperate (team working)

- *CROP* to guarantee all agents share the same picture*
  - Filter
    - Only relevant informations
    - Appropriate level of details
  - Share info relevant to on going tasks ,
  - Synchronisation

*Common Relevant Operational Picture

## CS challenges

# System Properties

- *Alarms/flags only to request an operator /agent action*
  - Clutter risk
  - Associated to action/decision of agent ‘in charge’
  - Hierarchised in relation with requested action response time and/or level of risk/danger
- *Flexibility*
  - Adaptability to Complex and unpredictable Situations
  - Interoperability (open to new system configurations)
  - Scalablility
    - Variable level of autonomy
    - Variable level of control
    - Variable number of operators
    - Variable skills of operators

# Some recommandations/conclusions

*Increase level of control (Niveau d'abstraction) : Mission Control vs A/C or sub systems control (Transparency to Ressources)*

- *Control What (goals) and not how*

  *e.g. Engage target x & y vs allocate target to system vs and control engagement (FFT, PID, Flight Path, Release of effector…)*

- *Cope with possible Heterogeneity of ressources :*

  – Different charactertistics (speed, maneuvrability) and capacity (FFT, Effector load….)

  – Challenge of Ressources capability description (exhaustive, variability along time)

- *Keep Possibility to Override or constrain system at whatever level*

  *e.g. automated/assisted sensor control contributing to target detection (goal) vs direct control of sensor due to « at the edge » operating conditions*

# Some recommandations/conclusions

- *Deal with Human Factors*
  - Operator skills (static) ,
  - Operator workload (dynamic) or tasks complexity
  - Selected level of involvement

- *Deal with variability of*
  - Contexts and Missions
  - Rules associated with the decision process :
- capture, implementation, validation, maintenance
- associated time scales (mission, campaign, system standards, MLU)
  - Operator skills

# Design process challenges

## *UCAV Autonomy Design?*

- *A Combination of Local autonomies :*
  - How to fix the appropriate levels?
  - How to fix the area of responsability of agents (Humen and machines)?
  - How to prevent combinatory explosion?

    *Complexity of systems comes more from number of configurations (and possible transitions) than intrinsic complexity of each configuration with associated impact on V&V*

⇒*How to reduce the number of options to be explored in detail (e.g. through MITL simulation)?*

# Design process challenges

***Autonomy, through capacity to make appropriate decisions, may influence Mission Success, Survivability and Safety***

- Effectiveness (Probability of kill)
- Abort rate
- Loss of Air Vehicle (shot, crash)
- Collateral damages

⇒*How to estimate «Autonomous System » Performance?*

- Domain of utilisation/validity
- Error rate

⇒*How to cope with variability of environment vs autonomous System V&V?*

# Conclusion

- *Due to the number of simultaneous tasks and variability of configurations ,achieving the appropriate definition of autonomy for UCAV systems based on tasks decomposition doesn't seem viable * from scratch*
- *Considering opportunity of new organisation of control segments the challenge is then to define the appropriate level of authority of operators through higher level of abstraction in control (from subsystem to package)*
- *Nevertheless operators will have to be kept in the loop due to the lethal nature of UCAV, relevant constraints on safety (airborne system) and unpredictable nature of contexts (targets and threats)*
- *Demonstrations of supporting Design and V&V process taking care of autonomy emergence gare requested*

(*)3 areas-MSS, 4cognitive steps OODA, up to 10 level of autonomy, 3 levels of system