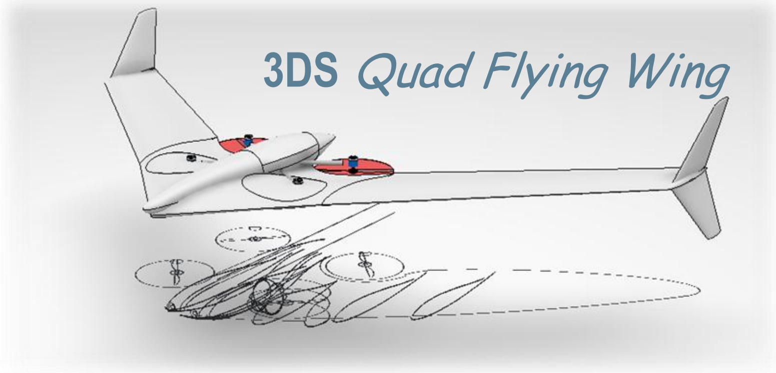
Realistic **3D**Experience to Play <u>UAS Mission</u>

Connecting the dots between Customer, User and Engineers




107
107

Video C-UAV_Scenario.wmv

Project | Dream

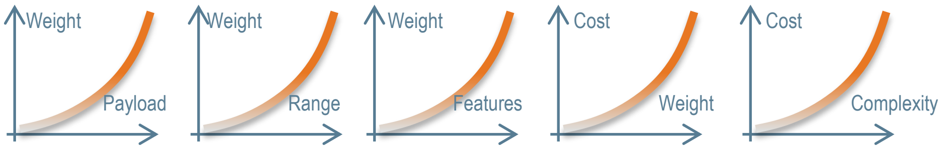
IF WE combine **the VTOL capabilities** of an **helicopter** with **the autonomy** & **cruise speed** of a **plane**, we could takeoff / land from ship deck and **cover vast areas** for **debris** and marine **pollution detection**

Can we **invent** a new UAV which **combines** all capabilities?

- Multicopter (VTOL(*) capable)
  - ✓ Can be operated anywhere
  - ✗ Short range and autonomy
  - ✗ Low speed
  - ✓ Flexible camera usage

- Aircraft (not VTOL capable)
  - ✗ Complex operations for take-off & landing
  - ✓ Long range
  - ✓ High speed
  - ✗ Forward flight limits flexibility of camera usage

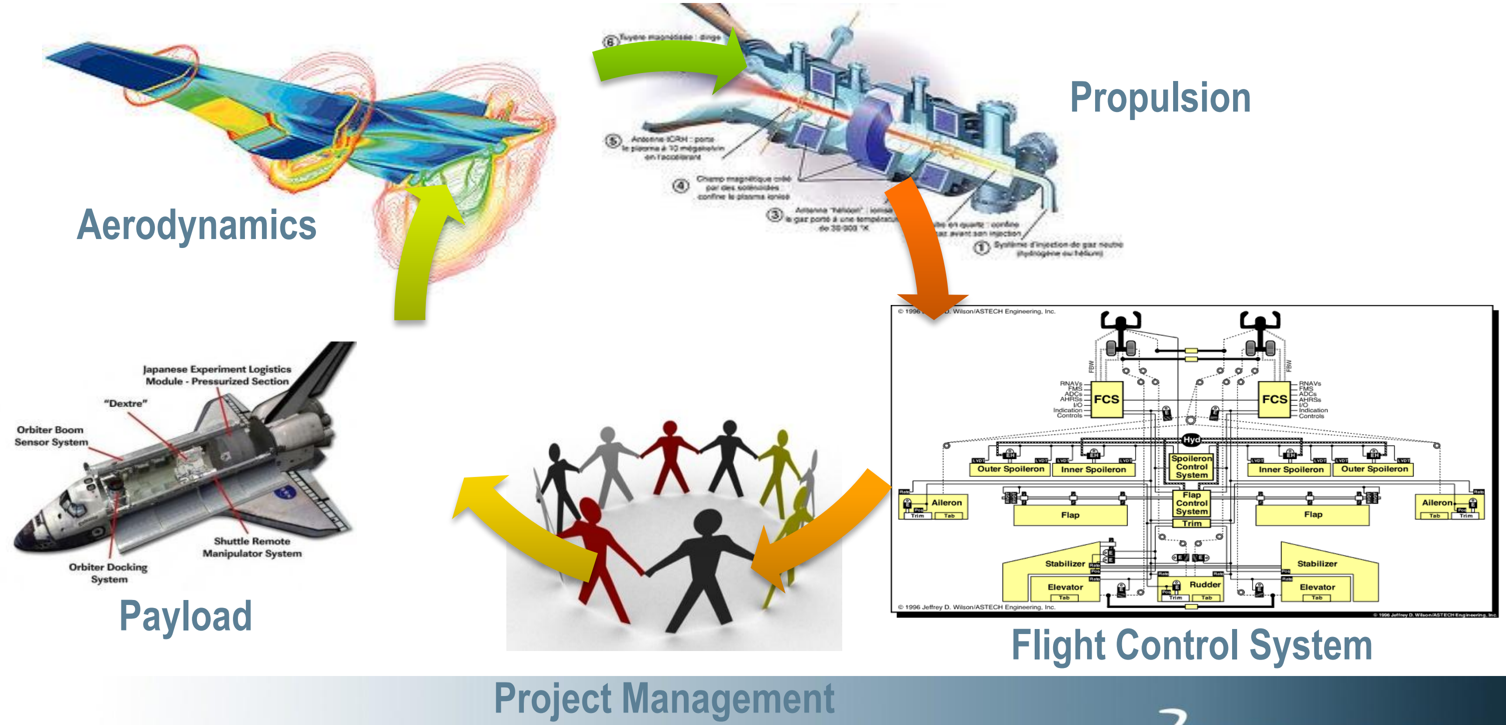
…And yet keep control on the total cost of ownership?



(*) VTOL : Vertical Take Off and Landing

How to get the best multi disciplinary product ?

Create Holistic **3D**Experience to imagine sustainable innovations



Objective | Play UAS Mission

Provide Users and Engineers perspectives on 3DExperience platform

Ground Control Station

3DExperience

HUD

Telemetry

Mission definition and execution

Flight **C**ontrol **S**ystem

Flight **D**ynamic **M**odel

Propulsion and **E**nergy

Equipment

Manual Flight

MAVLink or Micro Air Vehicle Link is a protocol for communicating with small unmanned vehicles
It can be used to transmit the orientation of the vehicle, its GPS location and speed.

Project | Requirements

- VTOL & Hovering Flight capabilities
- >= 2 hours mission with 30km range
- 60 kts horizontal flight speed
- 1 kg payload with GoPro 3 camera or equivalent + 3 axes stabilization and 2 axis (pan / tilt) controls
- Manual & automatic flight control with waypoint-based mission management
- <= 92 Db @ 3m
- <= $15,000 for POC

Payload | Camera Requirements

Vibration damping, stabilization and control is a must have

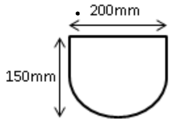
- The choice of using a gimbal will have major impact on UAV architecture

Vibration damping	No
Stabilization	No
Orientation Control	No
Dimensions	
Weight	

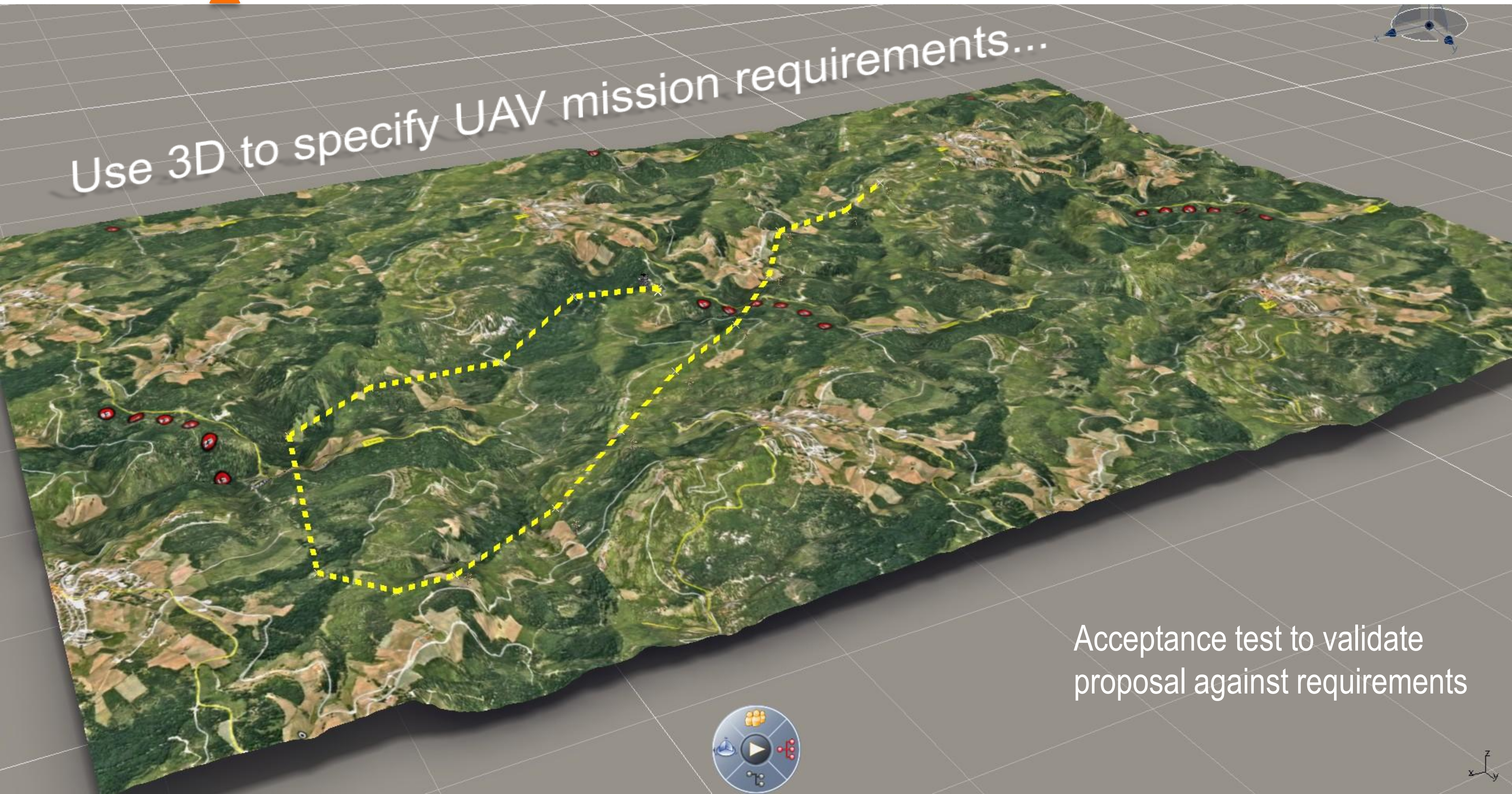
VS.

Vibration damping	yes
Stabilization	2 axes
Orientation Control	2 axes
Dimensions	
Weight	

- The Gimbal must be compact and light as sp by the followings maximum features:
  - Diameter:200mm,
  - Height : 150mm
  - Weight :400g

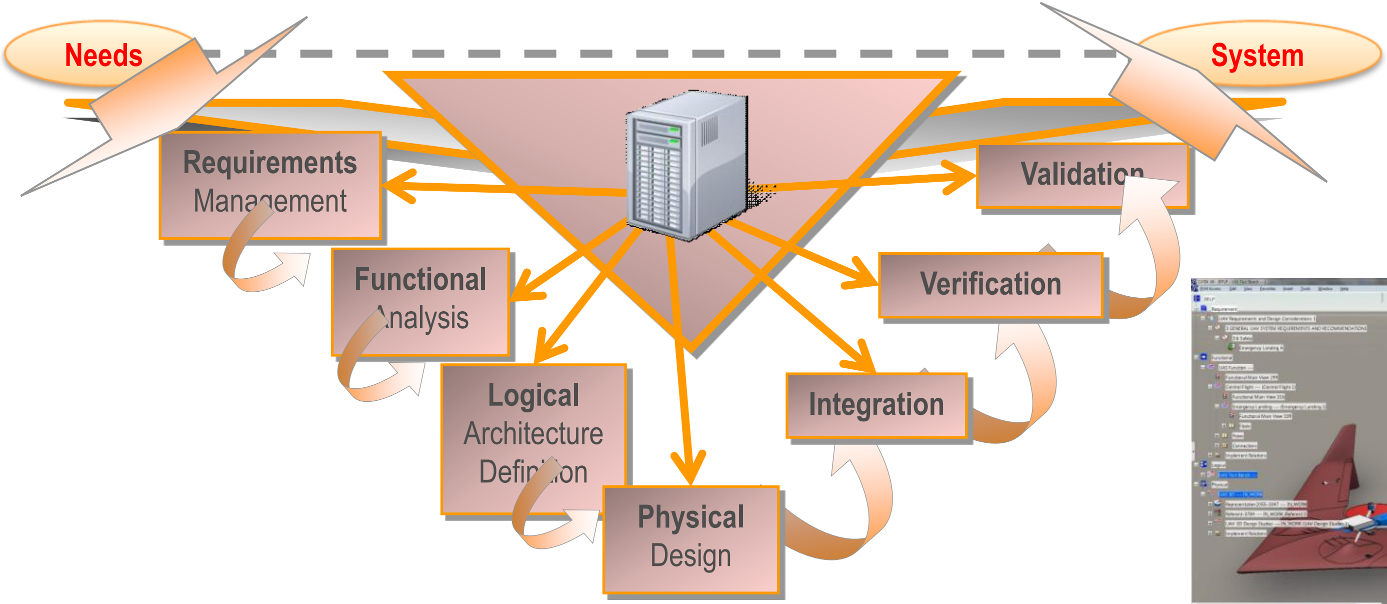


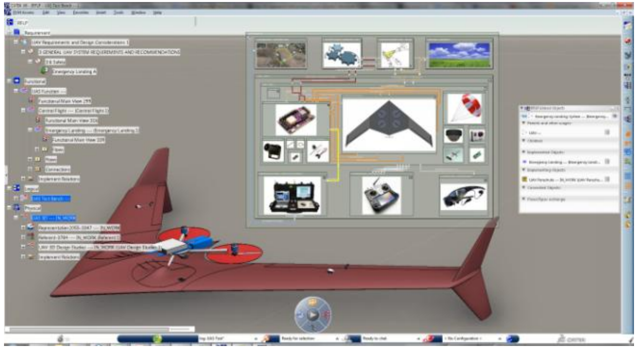
- The Gimbal must be fixed to the drone and detachable to be removed or replaced.
- The vibrations resulting from the drone must be damped in order not to affect the camera.
- A GoPro-like size camera
- The orientation must be controlled by the 7.4V PWM (Pulse Width Modulation)/50Hz drone autopilot.
- The camera must be protected (inside a glass or a Plexiglas dome for instance).
- Angular precision
  - $\pm$ 0.1° on Roll Axis
  - $\pm$ 0.5° on Pitch and Yaw Axis
- Total cost of gimbal <= 300€ (excluding camera)


Use 3D to specify UAV mission requirements...
Acceptance test to validate
proposal against requirements

RFLP at the heart of product development process

Ensure traceability from requirements to functions to logical architecture, behavior & 3D digital mockup

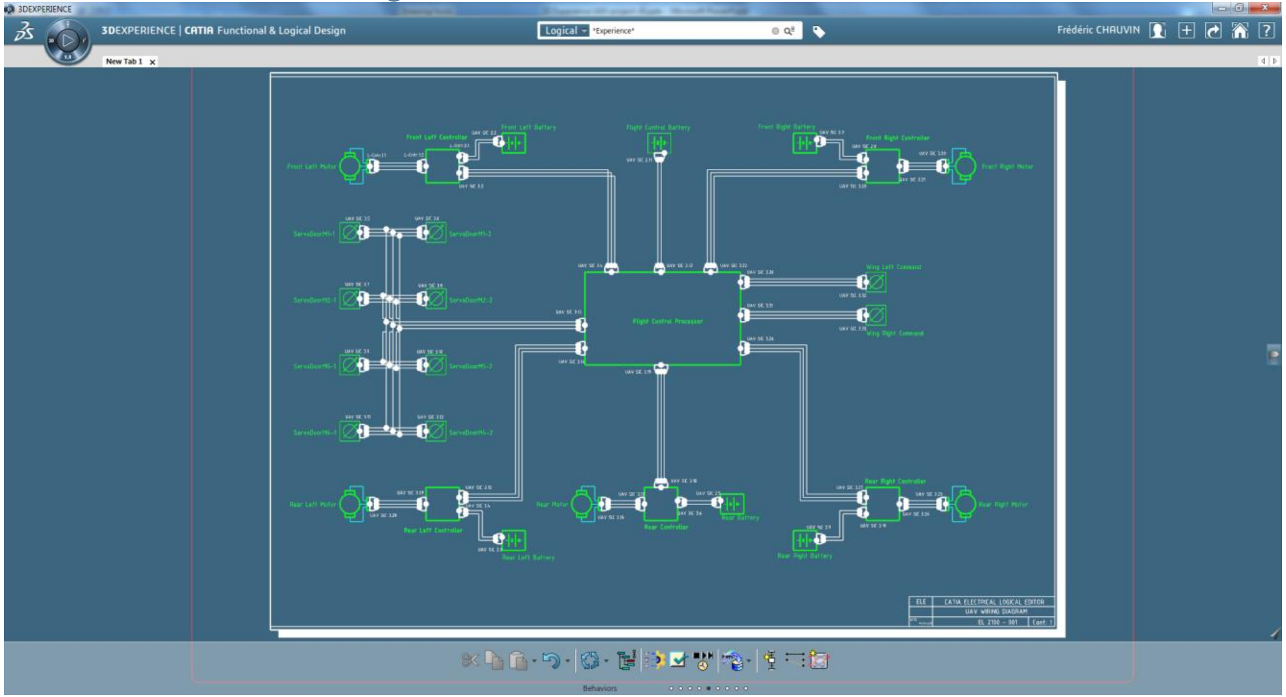




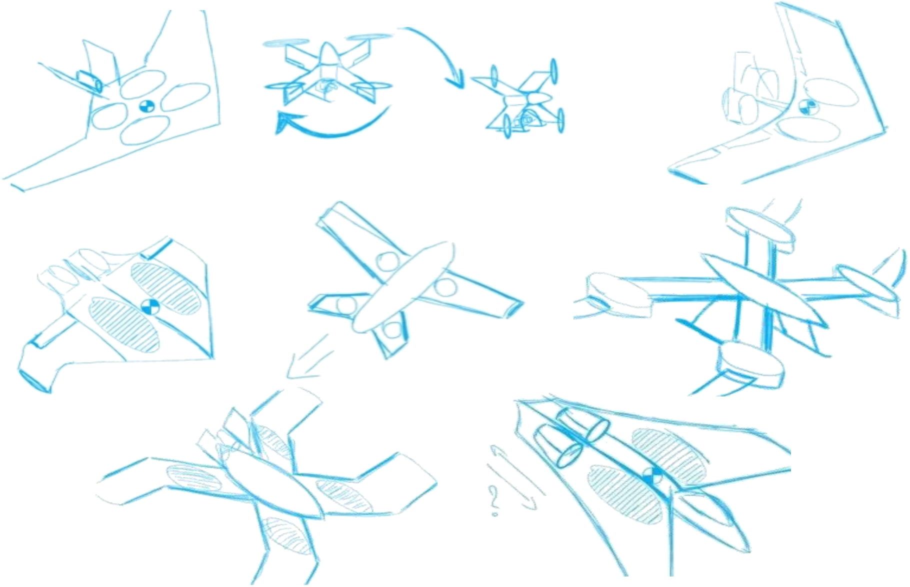
Logical : architecture and multi-discipline behavior definition

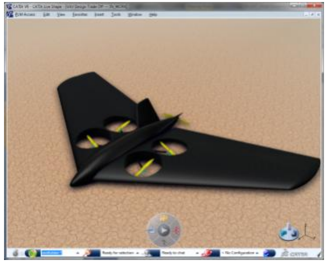
Logical : multi-discipline behavior definition

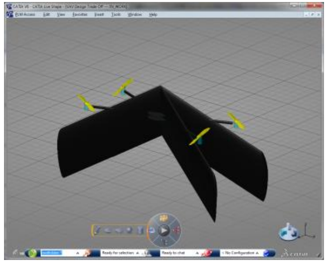
Example : electrical net diagram

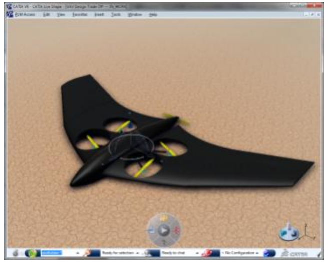


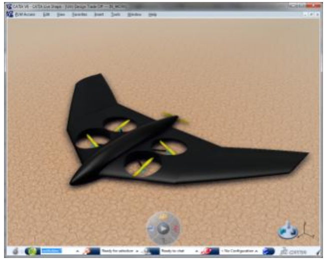
Fast concept sketching thanks knowledge based design

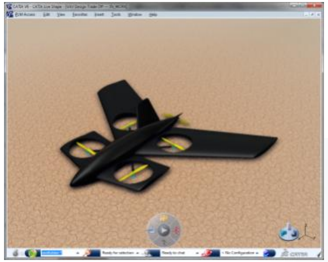


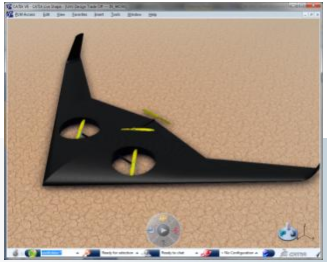


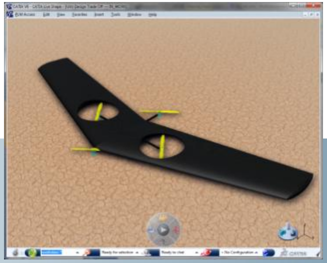


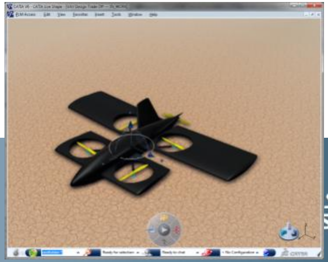


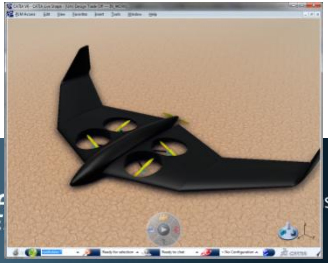




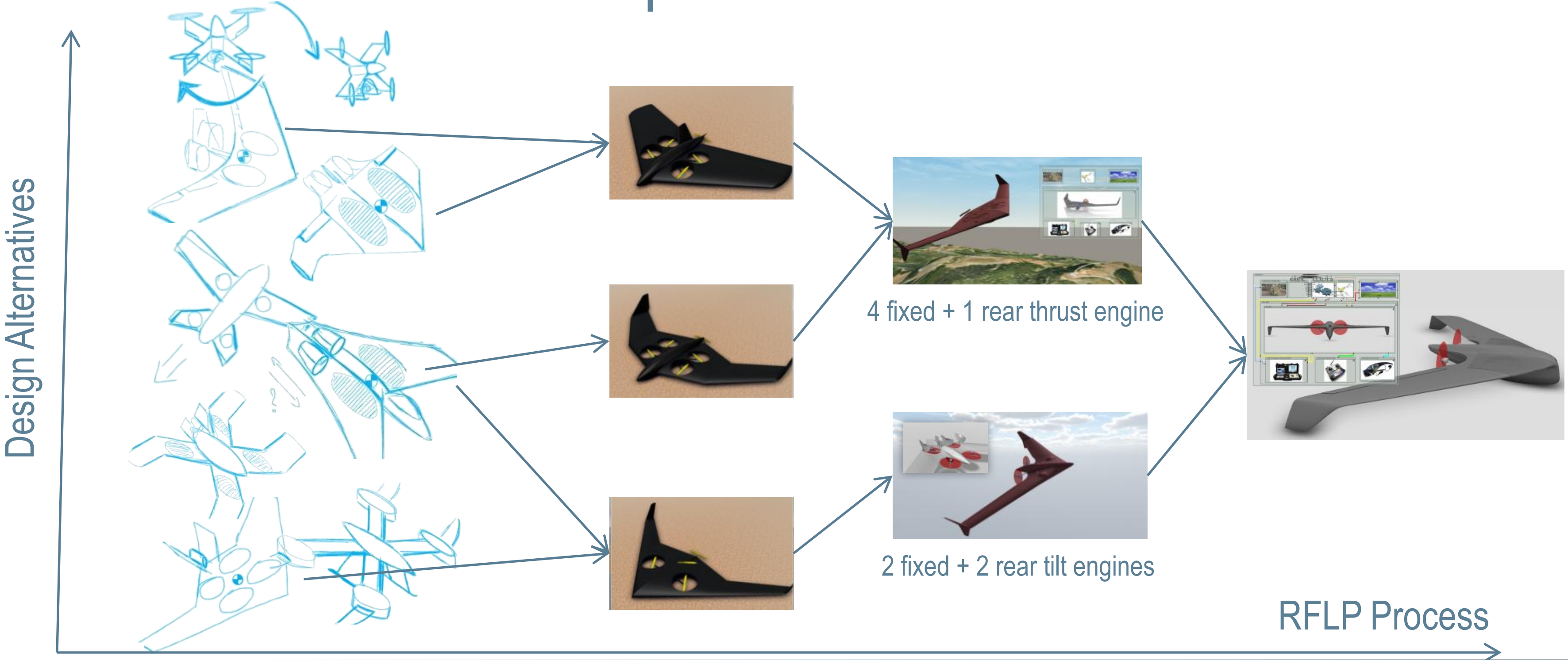






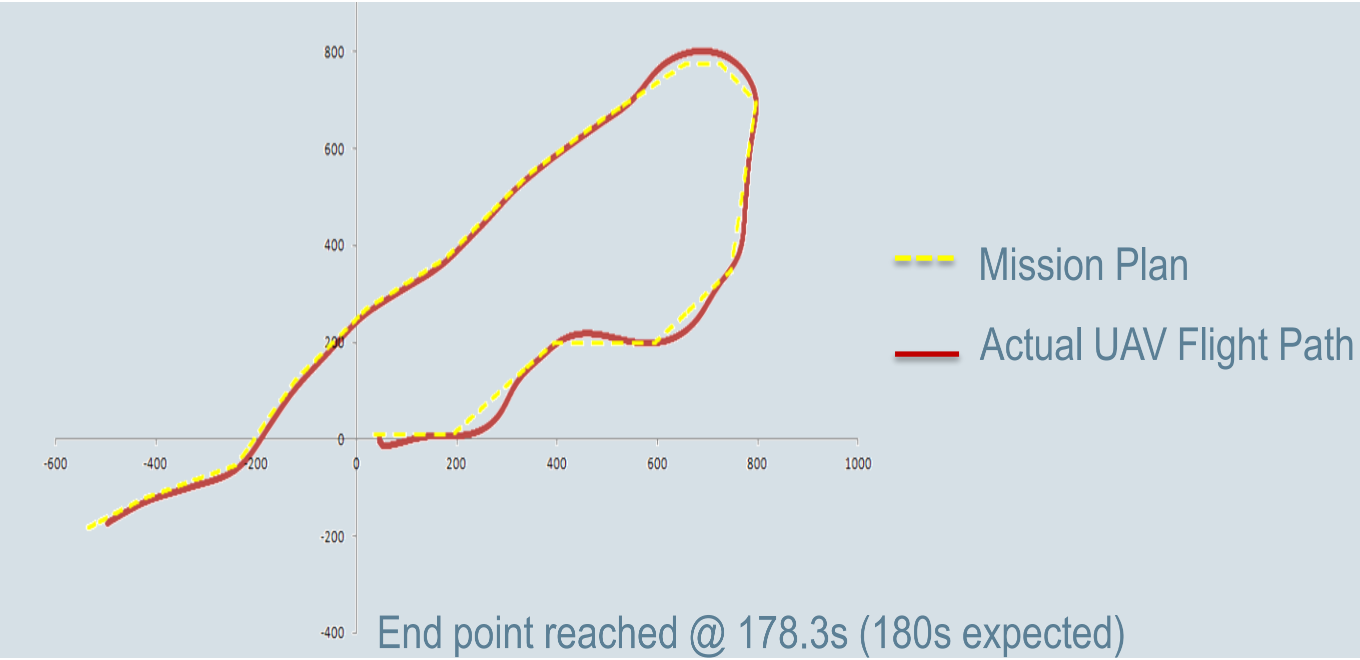


RFLP to support the trade off design study and best solution identification process



Play UAS Mission : Users and **Engineer** perspectives on the **3D**Experience platform

Play mission and compare to requirement use case




IFWE Compass | My 3DS Dashboard
All
Search
Configuration
Mission
PBS
Compare
SIGNAL QUALITY IN %
CONTROLLER TEMPERATURE IN DEGREE
CONTROLLER AMP IN A
9.6
A
DASHBOARD
Time 27 s
Signal quality 11.9 %
Battery voltage 26.4 V
Controller Temperature 17.5 degrees
Controller Amp 9.6 A
Battery Temperature 23 degrees
BATTERY TEMPERATURE IN DEGREE
23
DEG
BATTERY VOLTAGE IN V
26.4
V
GRAPHICS
SGNQ
CTLT
CTLA
BATT
BATV
TIMELINE
0 TAKE OFF
1 ON ZONE
2 Point of NO RETURN
3 END OF MISSION
4 LANDING

Technical insights

Behavior modeling

Behavior Modeling

Multi Disciplinary Model Based System Design

Flight Dynamic Model

$$\text{Lift}: L = ½*\rho*Vt^2*S_{rèf}[CL_\alpha + CLq\ \Omega q(c_{rèf}/2*Vt) + CLDf + CL_{de}]$$

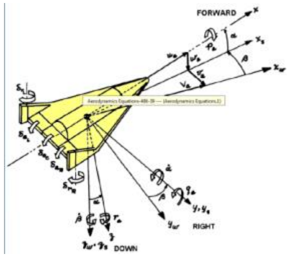
$$\text{Drag}: D = ½*\rho*Vt^2*S_{rèf}[Cd_\alpha + Cd_i + CdDf + Cd_{de}]$$

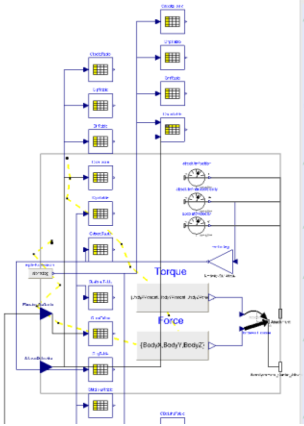
$$\text{Side force}: S = ½*\rho*Vt^2*S_{rèf}\ [Cy_\beta*\beta + Cyp\ \Omega r(b_{rèf}/(2*Vt))]$$

$$\text{Roll}: Mp = ½*\rho*Vt^2*S_{rèf}*b_{rèf}\ [Cl_{\beta*}\beta + Cl_p\ \Omega p(b_{rèf}/(2*Vt)) + Cl_r\ \Omega r(b_{rèf}/(2*Vt)) + Cl_{da}]$$

$$\text{Pitch}: Mq = ½*\rho*Vt^2*S_{rèf}*c_{rèf}\ [Cm_\alpha + Cm_{de} + Cm_q\ \Omega q(c_{rèf}/(2*Vt))]$$

$$\text{Yaw}: Mr = ½*\rho*Vt^2*S_{rèf}*b_{rèf}\ [Cn_{\beta*}\beta + Cn_p\Omega P(b_{rèf}/(2*Vt)) + Cn_{da} + Cn_r\Omega r(b_{rèf}/(2*Vt))]$$





Yaw
- Cn_β: yaw moment due to sideslip
- Cn_p: yaw moment due to roll rate
- Cnr: Yaw moment due to Yaw rate
- Cn_{da}: Yaw moment due to flap aileron deflection

Lift
- CL_α: lift due to alpha
- CL_{de}: lift due to elevator deflection
- CLDf: Lift due to Flap Deflection
- CLq: Lift due to Pitch rate

Drag
- Cd_α: drag due to alpha
- Cd_i: Induced drag
- CDdf: Drag due to flap deflection
- Cd_{de}: drag due to elevator deflection

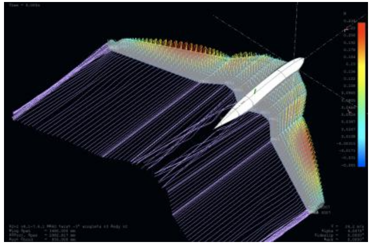
Side
- Cy_β: side due to β angle
- Cyp: Side due to Roll Rate

Vitesses de rotations
- Ωq: Pitch rate
- Ωp: Roll rate
- Ωr: Yaw rate

Roll
- Cl_β: Roll moment due to sideslip
- Cl_p: Roll moment due to roll rate
- Cl_r: Roll moment due to yaw rate
- Cl_{da}: Roll moment due to aileron deflection

Pitch
- Cm_α: pitch moment due to alpha
- Cm_q: pitch moment due to pitch rate
- Cm_{de} : pitch moment due to elevator deflection

$S_{rèf}$: Surface de référence
$c_{rèf}$: Corde de référence
$b_{rèf}$: Envergure de référence

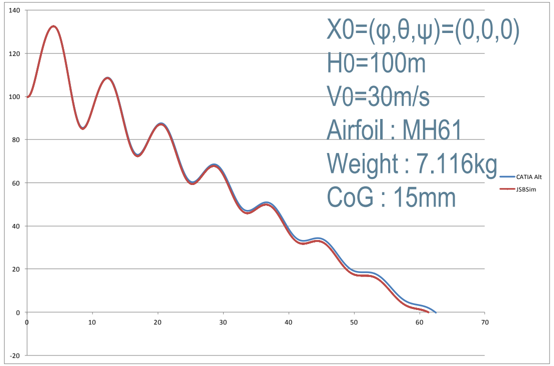


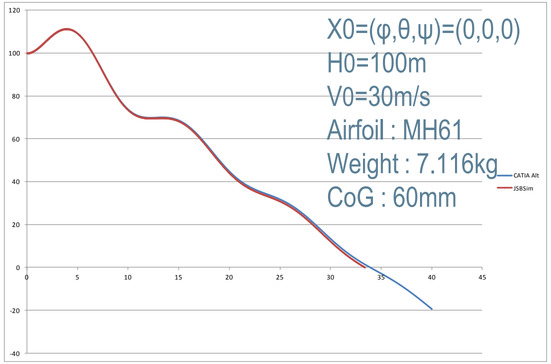
Aerodynamic coefficient (tabulated data) are computed by specialized CFD software

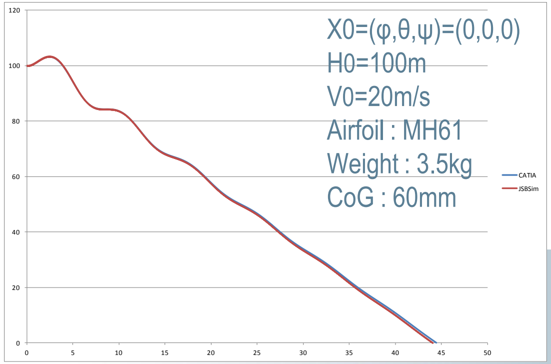
Free flight Test - Altitude vs time

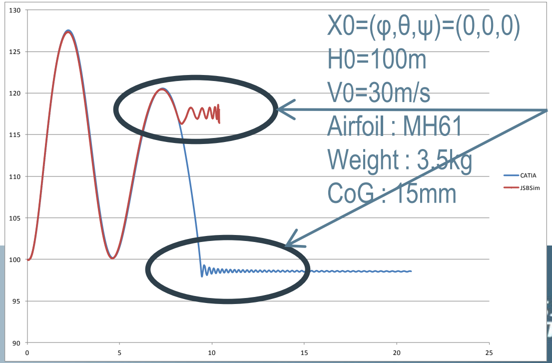
JSBSim is an open source flight dynamics model (FDM) that compiles and runs under many operating systems. The FDM is essentially the physics/math model that defines the movement of an aircraft, rocket, etc., under the forces and moments applied to it using the various control mechanisms and from the forces of nature.

Consistent results of CATIA vs JSBSim : a few tens lines of modelica code can replace thousands of C++ lines of solver









Stall properly predicted

Propeller model

- Model based on advance ratio to relate
  - Rotational speed
  - Airspeed
  - Torque
  - Thrust
  - Thrust Coef : Ct=T/(rho * n**2 * D**4)
  - Power Coef : Cp=P/(rho * n**3 * D**5)
  - Pe=Ct*J/Cp (efficiency)
- Use experimental data from manufacturer
  - Two x two dimensional tabulated data using CombiTable2D
  - Acausal table lookup => solved as equations

Advance ratio

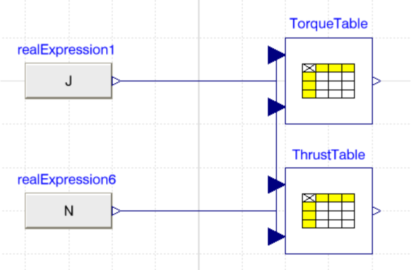
The advance ratio **J** is a non-dimensional term given by:[1]

$$J = \frac{V_a}{nD}$$

where

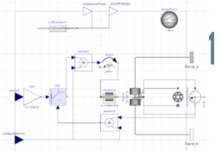
- $\mathbf{V_a}$ is the speed of advance per unit of time, typically the true airspeed of the aircraft or the water speed of the vessel
- **n** is the propeller's rotational speed in revolutions per unit of time
- **D** is the propeller's diameter

The advance ratio is a means of describing the incoming angle of the fluid relative to the propeller blade.

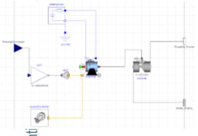


Electric Engine model(s)

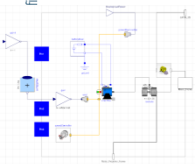
Manage multiple level of detail – **interchangeable** models to serve different scenarios



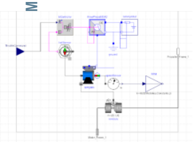
1. Speed Controlled Torque
   - Accurate dynamic response including friction
   - Mechanical power
   - Discrete control option



2. Quasi stationary ESC + PMSM
   - permanent magnet synchronous machine with integrated converter and field oriented control including current limitation and flux weakening.



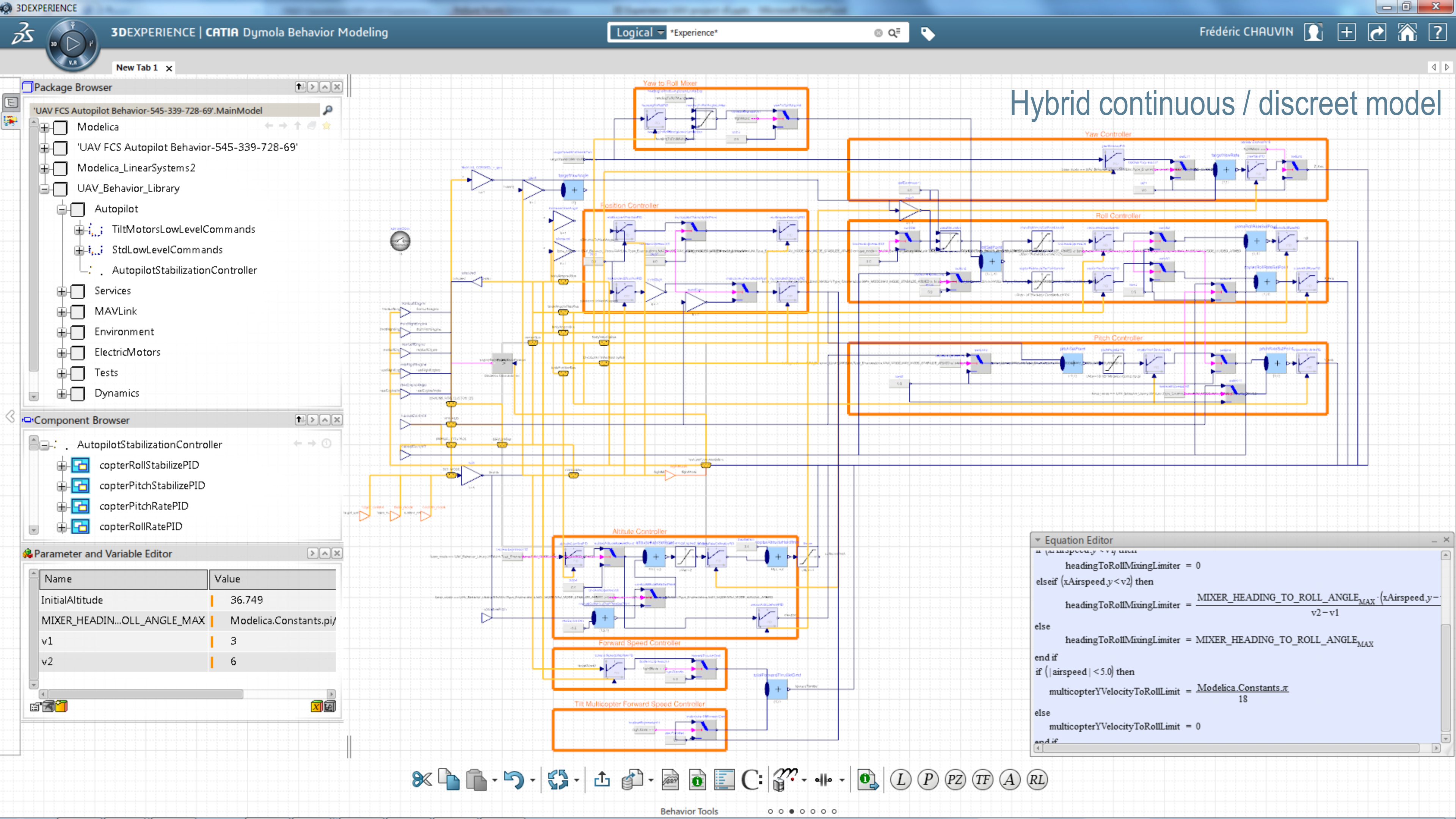
3. Transient ESC + PMSM
   - Includes transient effects



4. Transient ESC + full BLDC
   - Brushless controller, three phase DCAC, Hall sensor and PMSM

1. Real time flight of UAS with good estimation of propulsion dynamics and mechanical power consumption
2. Detailed behavior for accurate electric performance model on steady state
3. Advanced electric model with detailed transient behavior
4. Advanced brushless design or analysis

Hybrid continuous / discreet model



Aerospace : Military Programs

Some success stories…

CATIA ENOVIA

Sikorsky
A United Technologies Company

Bell Helicopter
A Textron Company

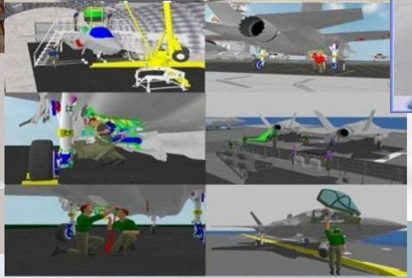
CATIA ENOVIA V6

CATIA ENOVIA DELMIA

LOCKHEED MARTIN
We never forget who we're working for™

NORTHROP GRUMMAN

CATIA



Our Customers… from shampoo bottles to airplanes

TRANSPORTATION & MOBILITY	RENAULT, TOYOTA, BMW, HONDA, VW, Valeo
AEROSPACE & DEFENSE	BOEING, DASSAULT AVIATION, EADS, SAFRAN, Bell Helicopter
MARINE & OFFSHORE	DELTAMARIN, MEYER WERFT, ISONAVAL S.L., DSME
INDUSTRIAL EQUIPMENT	BOBST GROUP, CLAAS, metso, ABB, SANYO
HIGH-TECH	NOKIA, Nikon, Panasonic ideas for life, ST, LG, PEGATRON
CONSUMER GOODS - RETAIL	GUESS, UNITED COLORS OF BENETTON., GAP, PATEK PHILIPPE GENEVE, s.Oliver, vf
CONSUMER PACKAGED GOODS - RETAIL	P&G, Barilla, Coca-Cola, amcor, Tetra Pak
LIFE SCIENCES	OLYMPUS, Medtronic, GE Healthcare, SANOFI, J&J
ENERGY, PROCESS & UTILITIES	BASF The Chemical Company, ALSTOM Power, SAMSUNG HEAVY INDUSTRIES
ARCHITECTURE, ENGINEERING & CONSTRUCTION	SMEDI, SAINT-GOBAIN, KAJIMA, SKANSKA, ARUP
FINANCIAL & BUSINESS SERVICES	BNP PARIBAS, LA POSTE, pwc, IBM
NATURAL RESOURCES	RioTinto, Gold Fields, AEM, Cerrejón, Technip, ExxonMobil

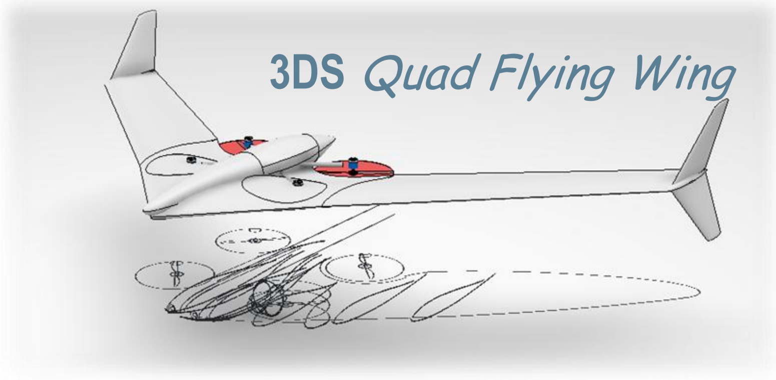
Enabling Technology to Achieve Complex Goals

- From Digital Mock-Up (DMU) to Functional-DMU
- Enabling full End to End System Engineering Process
- Advanced On-line Collaboration (key)
- A fully integrated system built on an industrial-strength Product Data Management
- Using 3D to communicate

- **Outpace the Threat and Deliver Advanced Fully Integrated Capabilities**
- **Reduce acquisition cycle time and total ownership cost**
- **Major Strategic Thrusts:**
  - **Enable Lead Systems Integration Processes**
  - **Support Rapid Acquisition**
  - **Support the workforce strategy for the next generation of system complexity**
  - **Mission Assurance**

UAS Experience

Unmanned **A**erial **S**ystem
on **3D**Experience Platform



Frédéric CHAUVIN

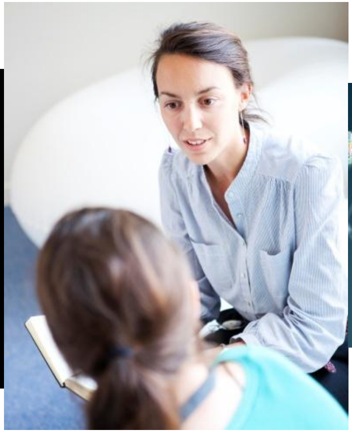
3DEXPERIENCE

Who Are We?

Our Company

a **Scientific** company

Serving **Science, Technology** and **Art** for a sustainable society



11,000 passionate people

- 106 nationalities
- One global R&D/34labs
- A **unique** software platform

170,000 enterprise customers

- 12 industries in 140 countries
- >10 million on premise users
- >100 million online users

3,500 partners

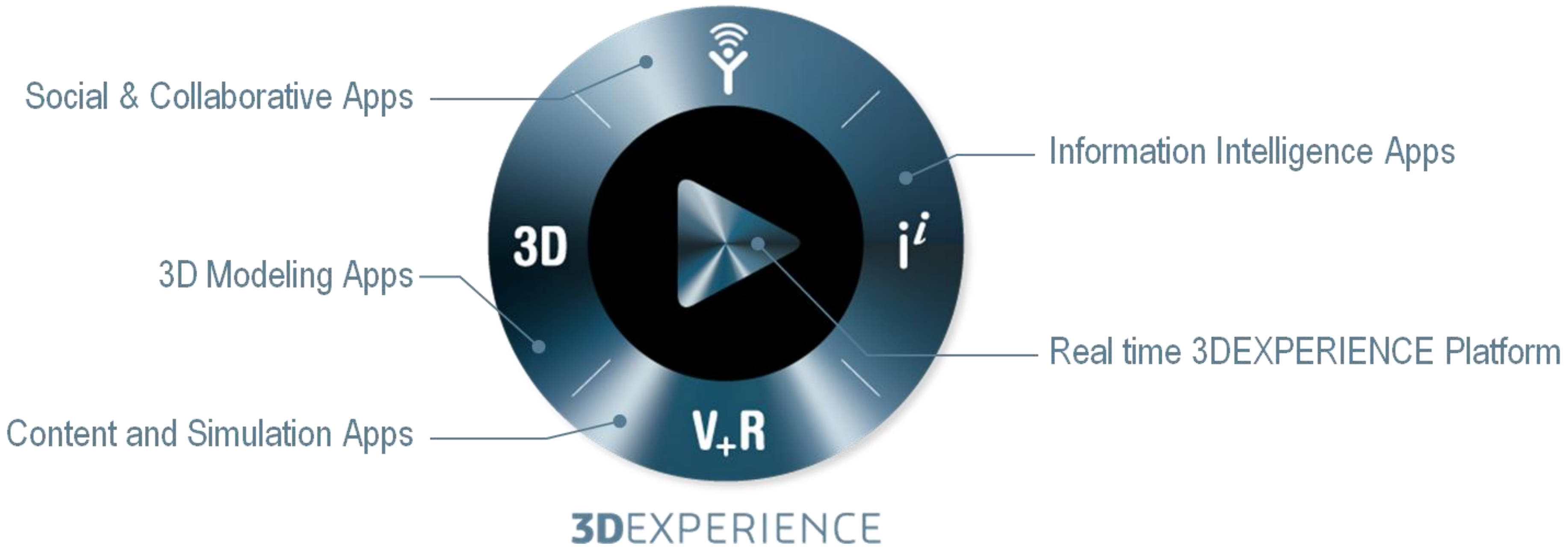
- Research & Education
- Software & Technology
- Sales & Services

Long-term driven

- Majority shareholder control
- **Revenue: $ 2.6 Bn***
- Operating margin: 31.6%*

** Non-IFRS*

Key Elements of Our Platform

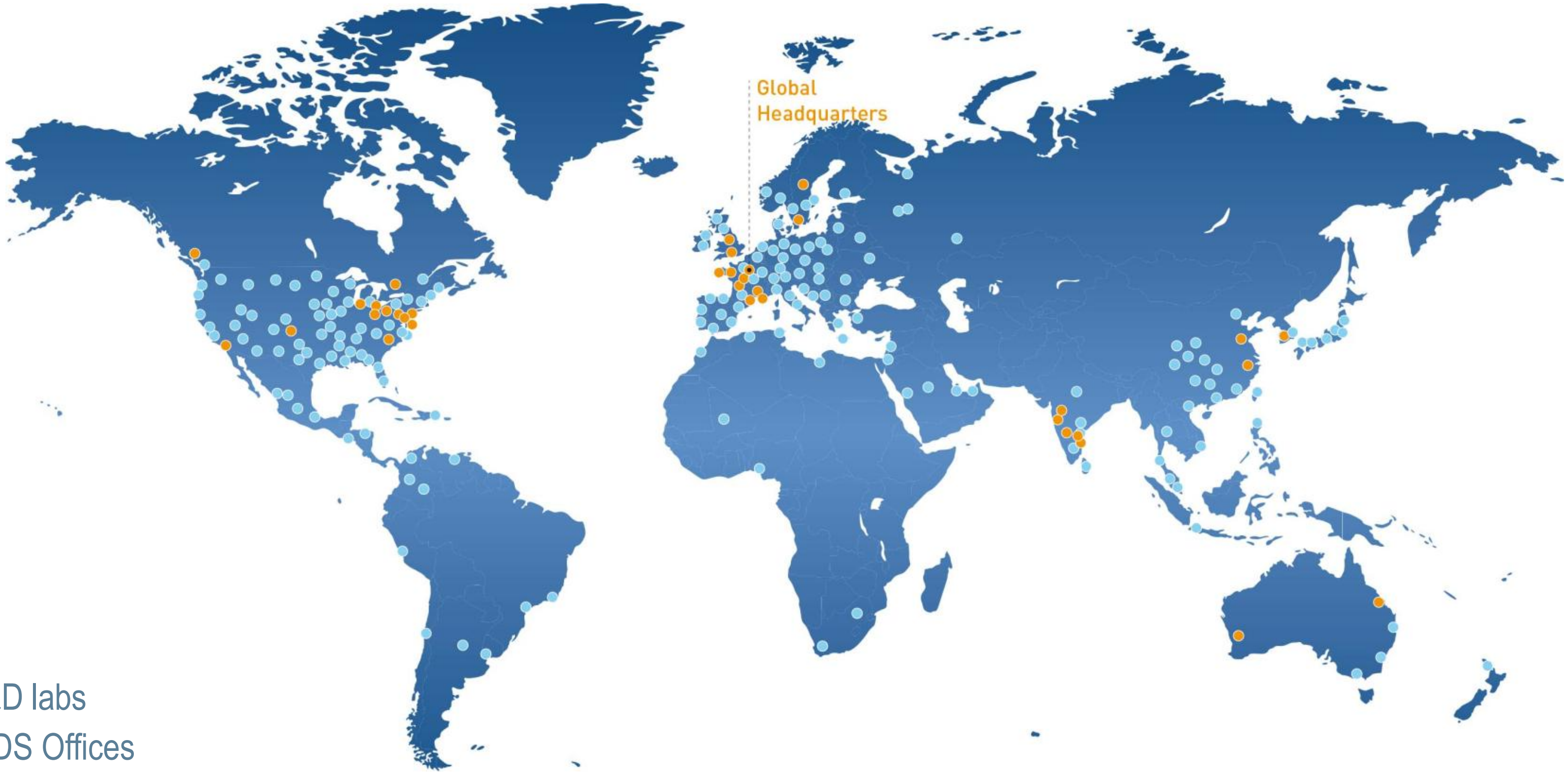


Our **3D**EXPERIENCE Platform

Our **3D**EXPERIENCE
PLATFORM

Powers
our Brands

Our Presence



- 34 R&D labs
- 140 3DS Offices

IF WE™

Systems Modeling and Simulation Working Group (SMSWG)

Objective:

- **NAFEMS and INCOSE agreed to a mutually beneficial strategy to develop a collaborative relationship that would benefit both the organizations and their members.**

The mission of the Systems Modeling & Simulation Working Group (SMSWG) is to:
• develop a vendor-neutral, end-user driven consortium
• promote the advancement of the technology and practices associated with co-simulation of systems engineering and engineering analysis
• act as the governing body of standards in this space
• drive the strategic direction for technology development in this space

This includes education, communication, promotion of standards, and development of requirements that will have general benefits to the simulation and analysis communities.

The Result

Call to Action

- Contact Edward A. Ladzinski (el4@3ds.com) to join