3rd European LS-DYNA Conference

F - Ma = 0
The unique certitude in Aerospace ?

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Acceleration Landscape

Dynamics in Aerospace

Acceleration Landscape

General Formalism of Dynamics

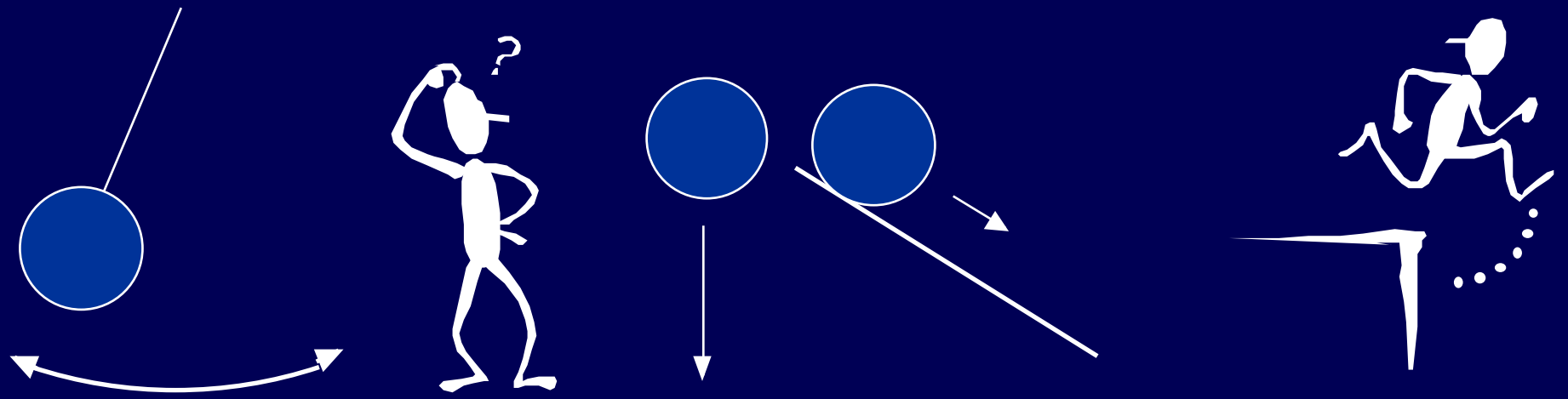
Stability and Linearity

Technique of Model

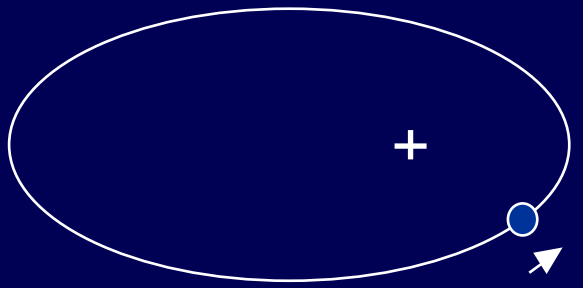
Acceleration

The origin : free fall flight

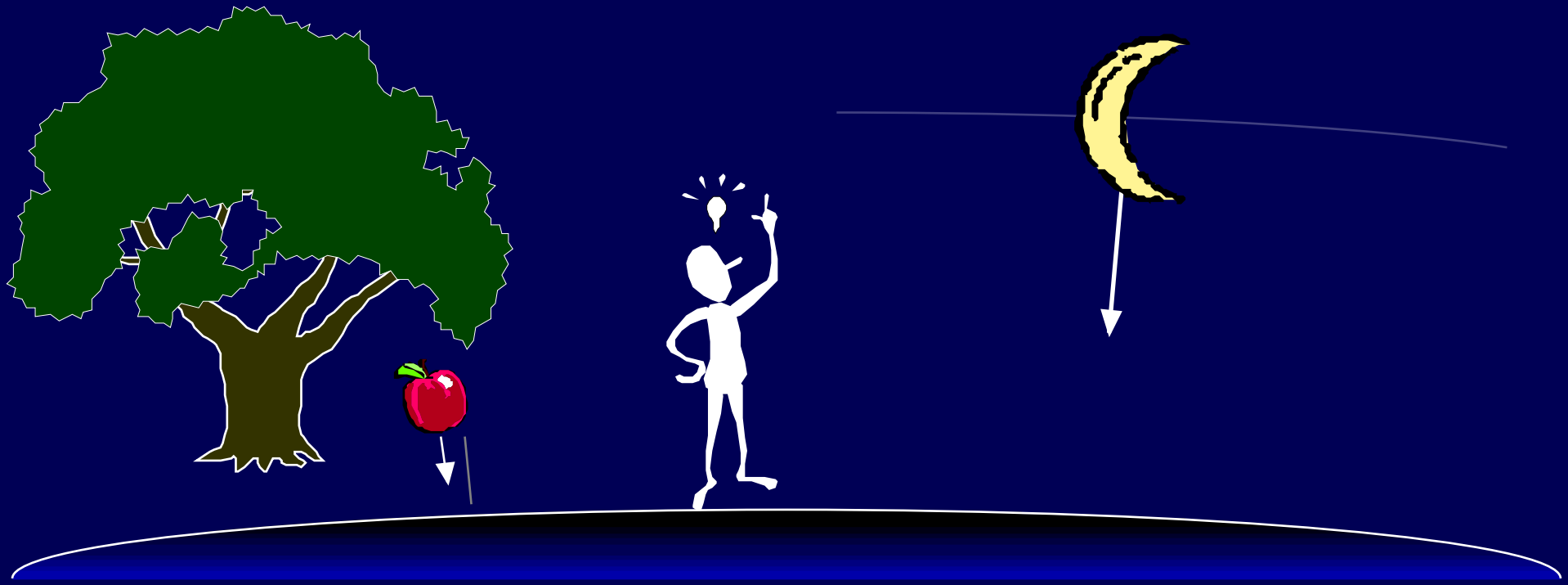
Galilee Kinematics F - Mg = 0



Kepler Orbital Kinematics



Newton General Dynamics F - Ma = 0



General Dynamic Formalism

Constitutive equations

Newton : $F - Ma = 0$

Derivative & vectorial application

General Resulting Theorems : $R_{ext} - p^{\cdot} = 0$

sum (& moment) applied to external **system** forces

General 1st degree natural kinetik conservations

Newton (cont'd) :

Real Power Formulation : $P_{abs} - E_{kin}^{\cdot} = 0$ for **working** forces

General 1st degree natural energy conservation (E_{pot})

Lagrange - Hamilton : $(F - Ma)q^* = 0$

Virtual Power Formulation : $[\mathcal{L}_k](E_{kin}) - Q_k = 0$

applied to canonical virtual motions on q_k geometrical parameters

Lagrange (cont'd) :

$$[\mathcal{L}_k] \equiv \frac{d}{dt}\frac{\partial}{\partial \dot{q}_k} - \frac{\partial}{\partial q_k} \quad \text{and} \quad Q_k = Q_{(load)k} + Q_{(diss)k} + Q_{(n.-hol.)k}$$

Lagrange-Routh Kinetik Prime Integral $\sum_{Routh} \equiv E_{\partial lag}/\partial \dot{q}_k - \mathcal{G}$

valid if $k \hat{o} [\mathcal{L}_k](E_{lag}) = 0$ and $\mathcal{G}(q_j ; t) \hat{o} \partial E_{lag}/\partial q_k = \mathcal{G}$

Lagrange-Hamilton Energy Prime Integral $E_{Hamilton} \equiv E_{lag2(qj\cdot)} - E_{lag0(qj\cdot)} + \mathcal{F}$

valid if k, $Q_{(load)k} = [\mathcal{L}_k](E_{pot})$ and $Q_{(diss)k} = 0$, and if $\mathcal{F}(q_j ; t) \hat{o} \; t : \partial E_{lag}/\partial t = \mathcal{F}$,

and if in addition all non-holonomic relations are homogeneous in the $\dot{q}_j$.

That was explicitated by **Painlevé** : $E_{Painlevé} \equiv E_{kin2} - E_{kin0} + E_{pot} - \sum_j [\dot{q}_k (\partial E_{pot}/\partial \dot{q}_k)]$

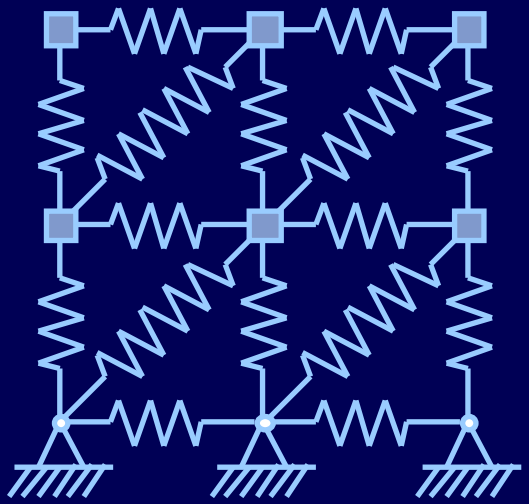
Acceleration Landscape

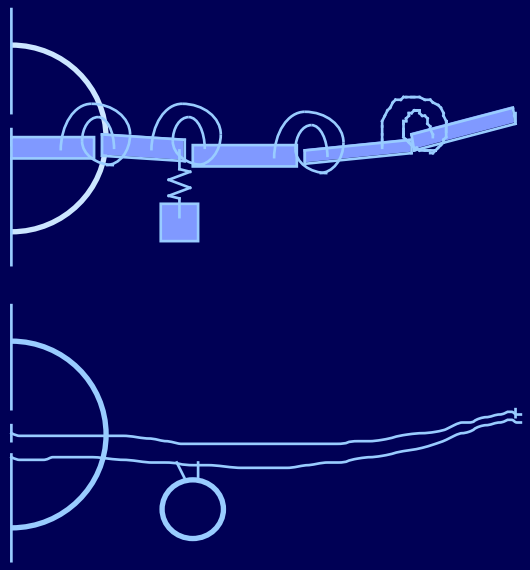
General Formalism of Dynamics

Stability and Linearity

Technique of Model

Linear Dynamics





Rational Dynamics : $[\mathcal{L}_k](E_{kin}) - Q_k = 0 \;\; ; \;\; [M]\{q\}^{\cdot\cdot} + [K]\{q\} - \{q\}_e = 0$

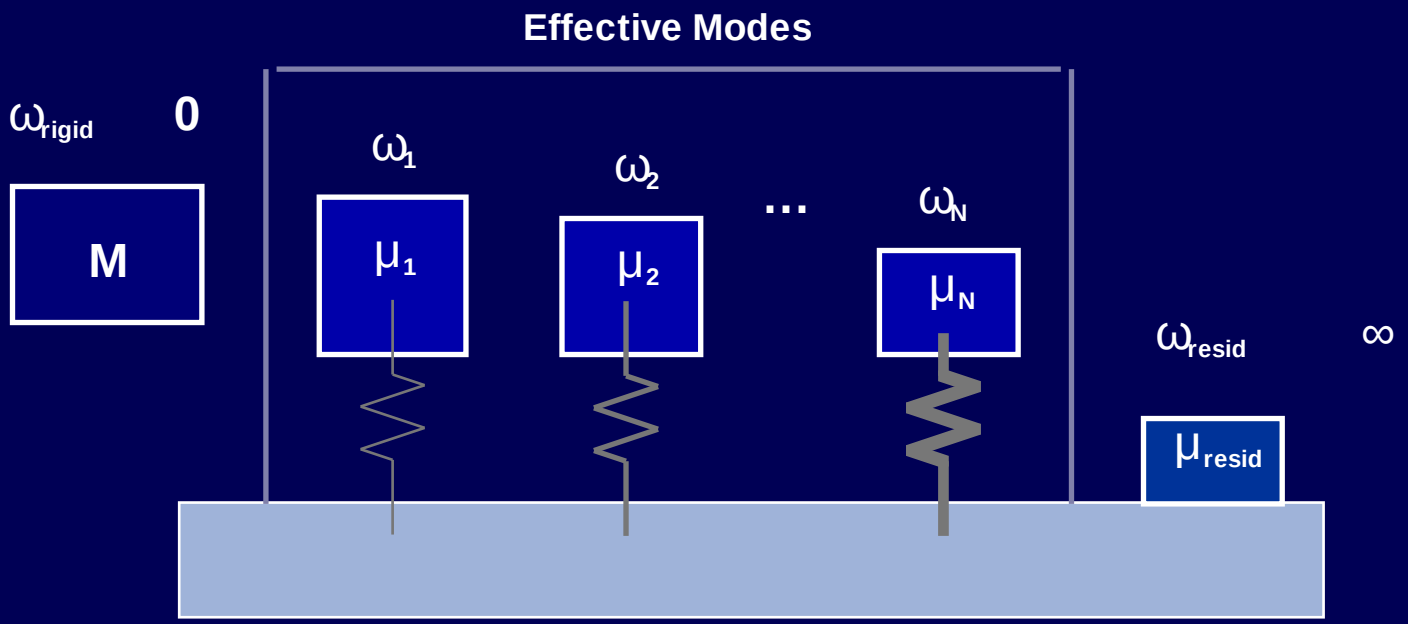
Continuous Beams & Shells :

$$\rho h\, W^{\cdot\cdot} - EI\, W'''' - \lambda_z = 0$$

$$\rho S\, U^{\cdot\cdot} - ES\, U'' - \lambda_x = 0$$

Linear Harmonic Analysis (Modes & Waves)

Harmonic Diagonalization / free solution



Modes : $\omega_i = \sqrt{\frac{k_i}{m_i}}$ **Waves :** $c_j = \sqrt{\frac{E_j}{\rho_j}}$

Stability & Linearity

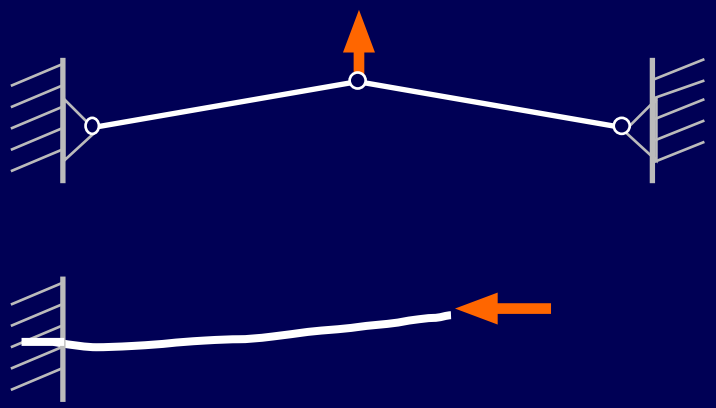
$y'' \pm y - a = 0$
(Newton/Lagrange)

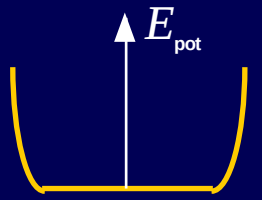
$s^2 \pm s - \alpha = 0$ (Laplace/Fourier)

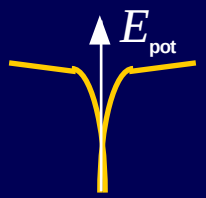
exp complex

- evolution : real
- vibration : imag

Static

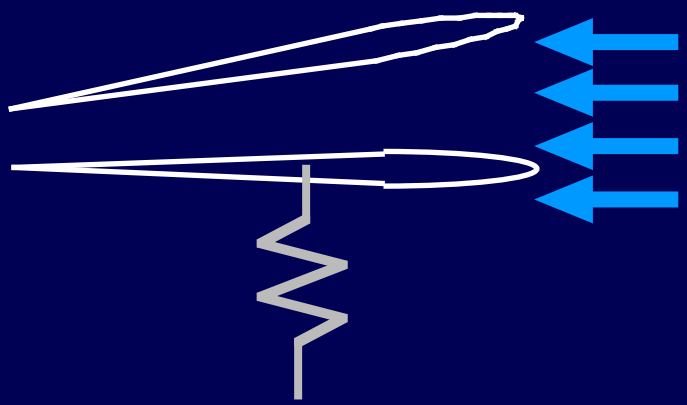


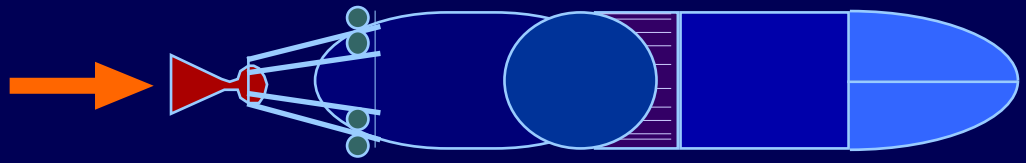


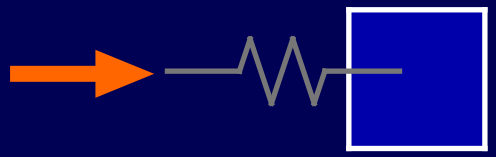


Geometrical and/or topological non-linearities

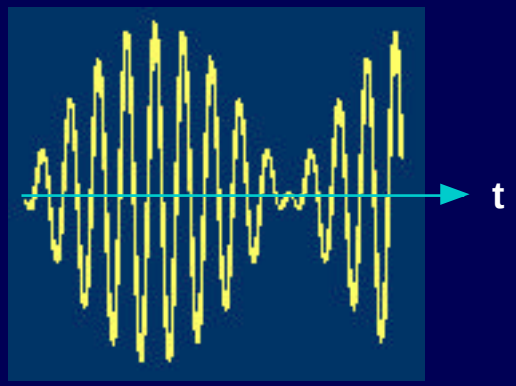
Dynamic instability

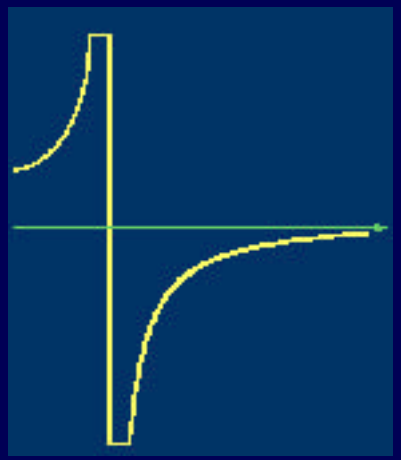






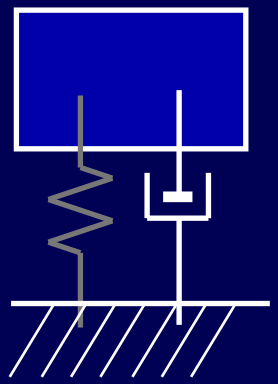
Coupling & Resonance





Solid Damping

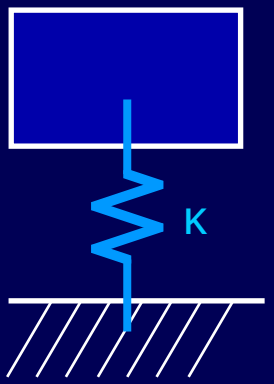
Viscous



$m\ddot{x} + r\dot{x} + kx - f = 0$

$2P_{visc} = r(\dot{x})^2$

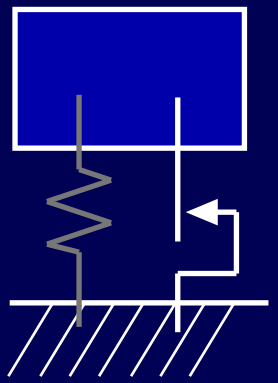
Structural



$m\ddot{x} + Kx - f = 0$

K C

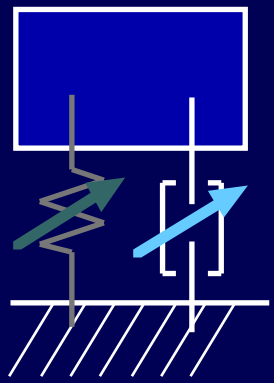
Slide



$m\ddot{x} + f(\dot{x}/|\dot{x}|) + kx - f = 0$

Heaviside

Real



$m\ddot{x} + f_{damp} + f_{elast} - f = 0$

Polynomial

Acceleration Landscape

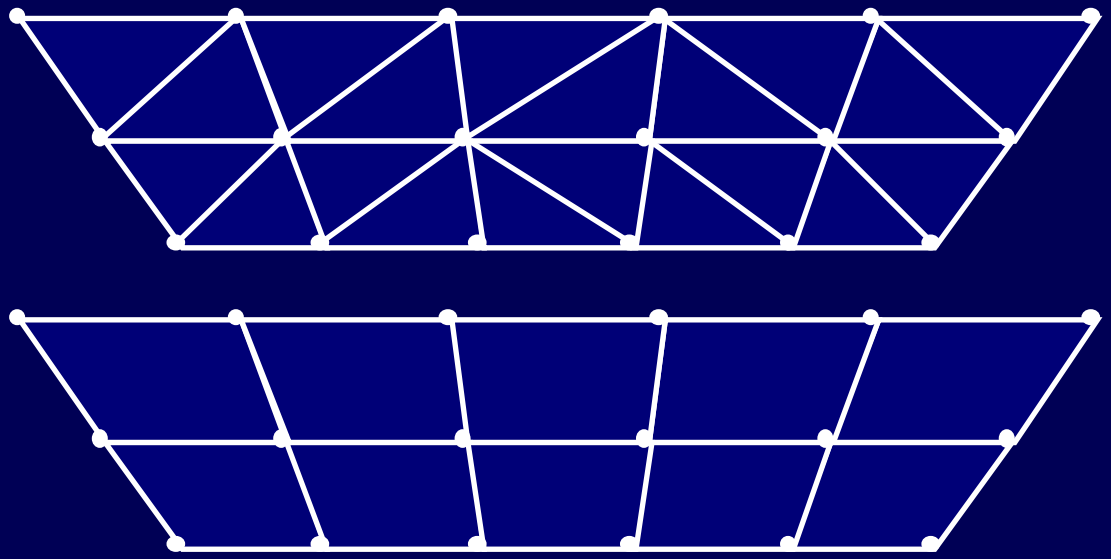
General Formalism of Dynamics

Stability and Linearity

Technique of Model

Numerical Modelling

Lagrange-Ritz Deflection FEM Mesh



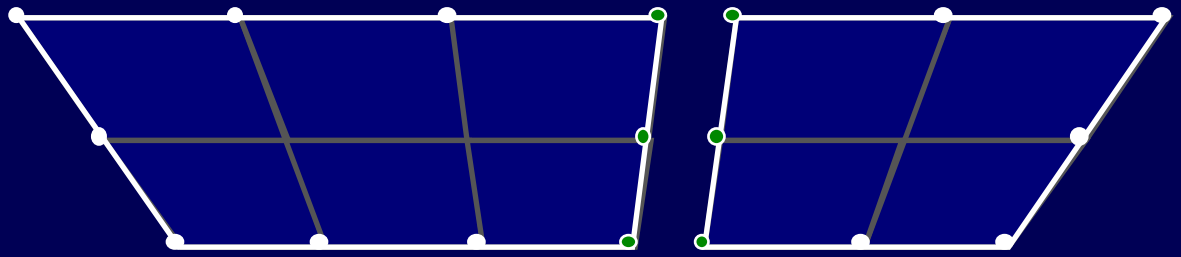
Autom triang/tetra

Quad/hexa

Local element matrix
Assembly
Inversion

Natural FEM Developp^{ts}

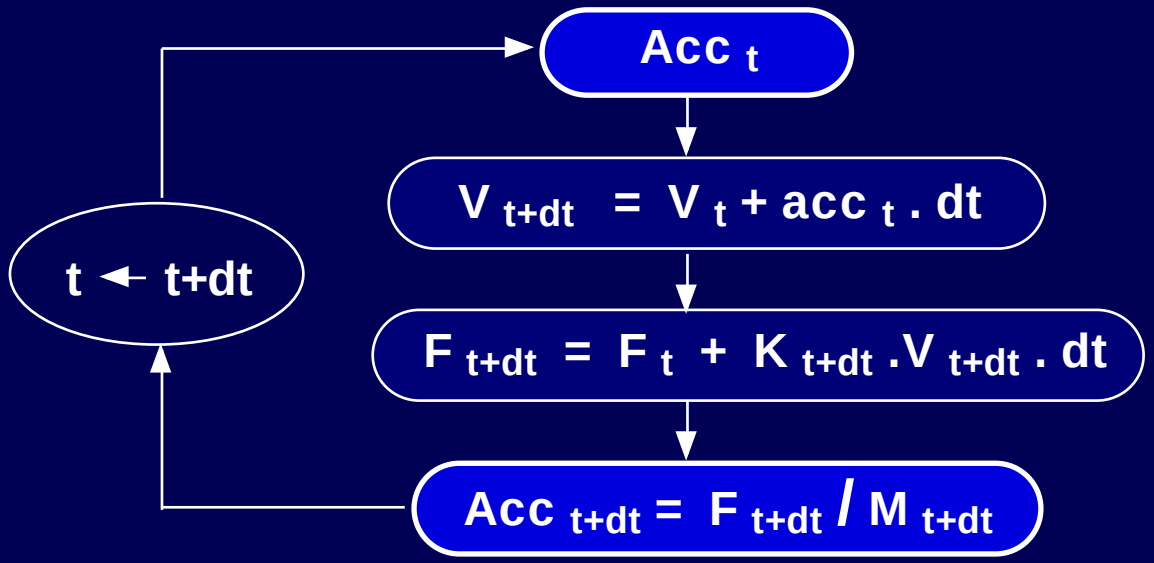
- Substructure
  Superelement
  Condensation
  Frontier elements



- Explicitation

  Evolutive

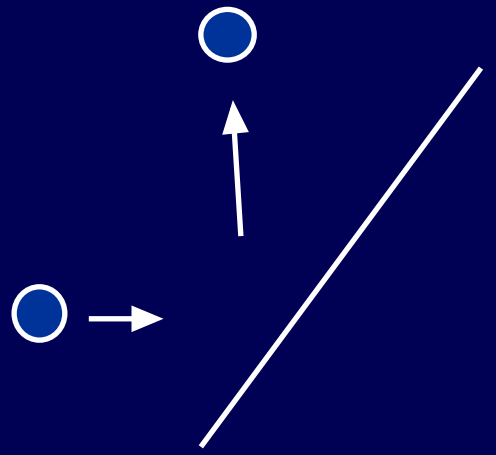
    geometry
    topology
    materials



SPH evolution

Newton's Solid Percussion Fluid Mechanics

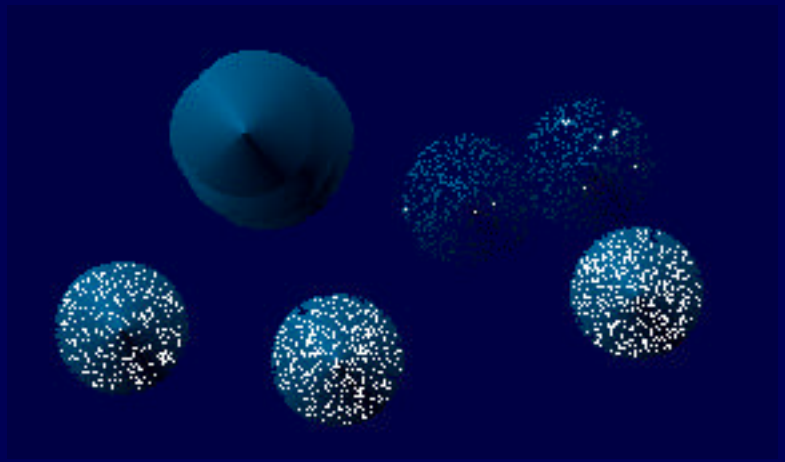
$$2p = \rho v^2 \cos^2 i$$



Valid in rarefied atm and/or hypersonic
Not valid for classical fluid

Smooth Particles

Natural Lagrangian
modern extension

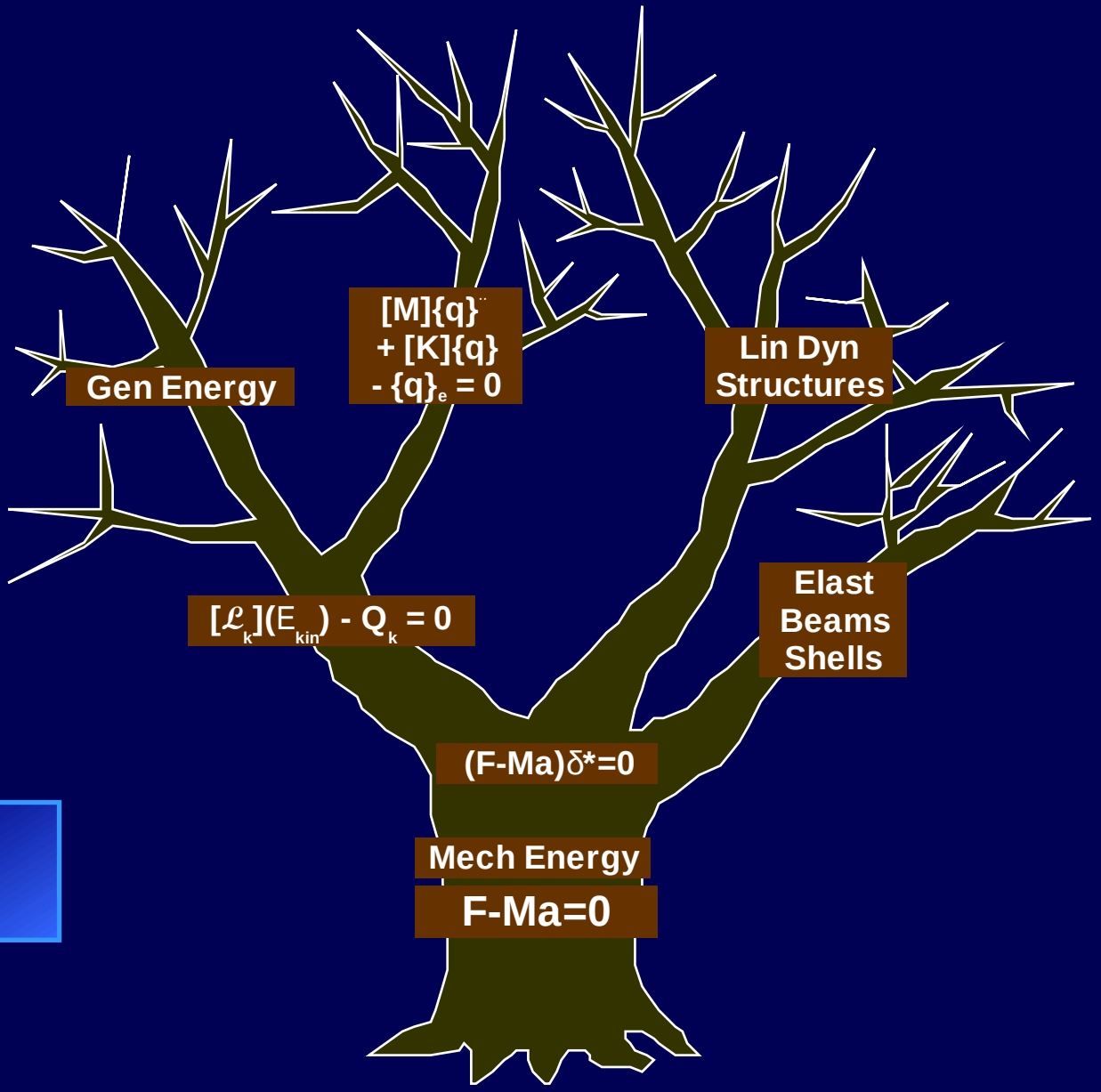


The Engineer's Panoply

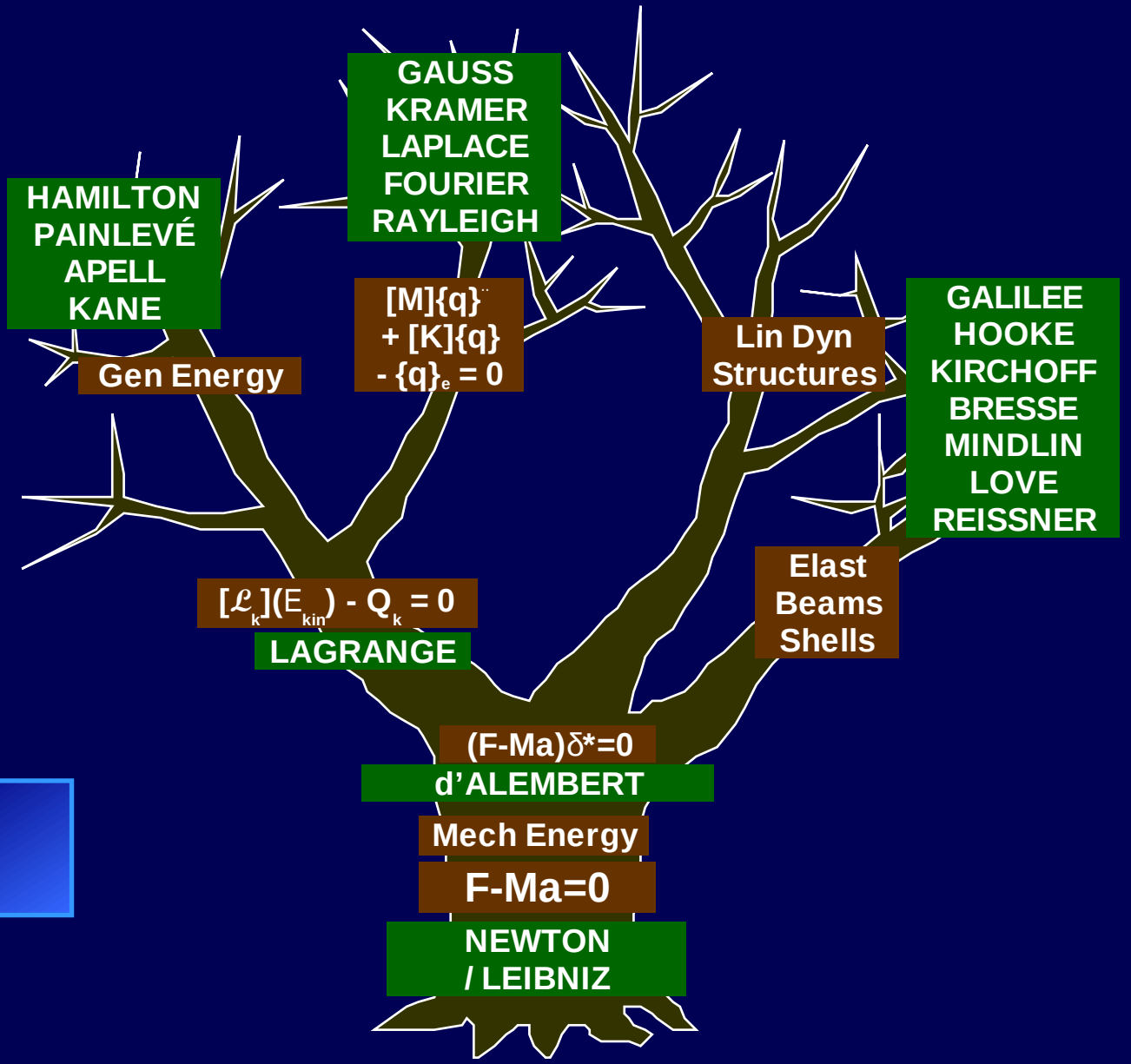
Model	all "by hand" numerical solving analogical solving numerical model
Test	physical analogy scale specimen prototype

Context : Goal/facilities
Performance / Cost / Time

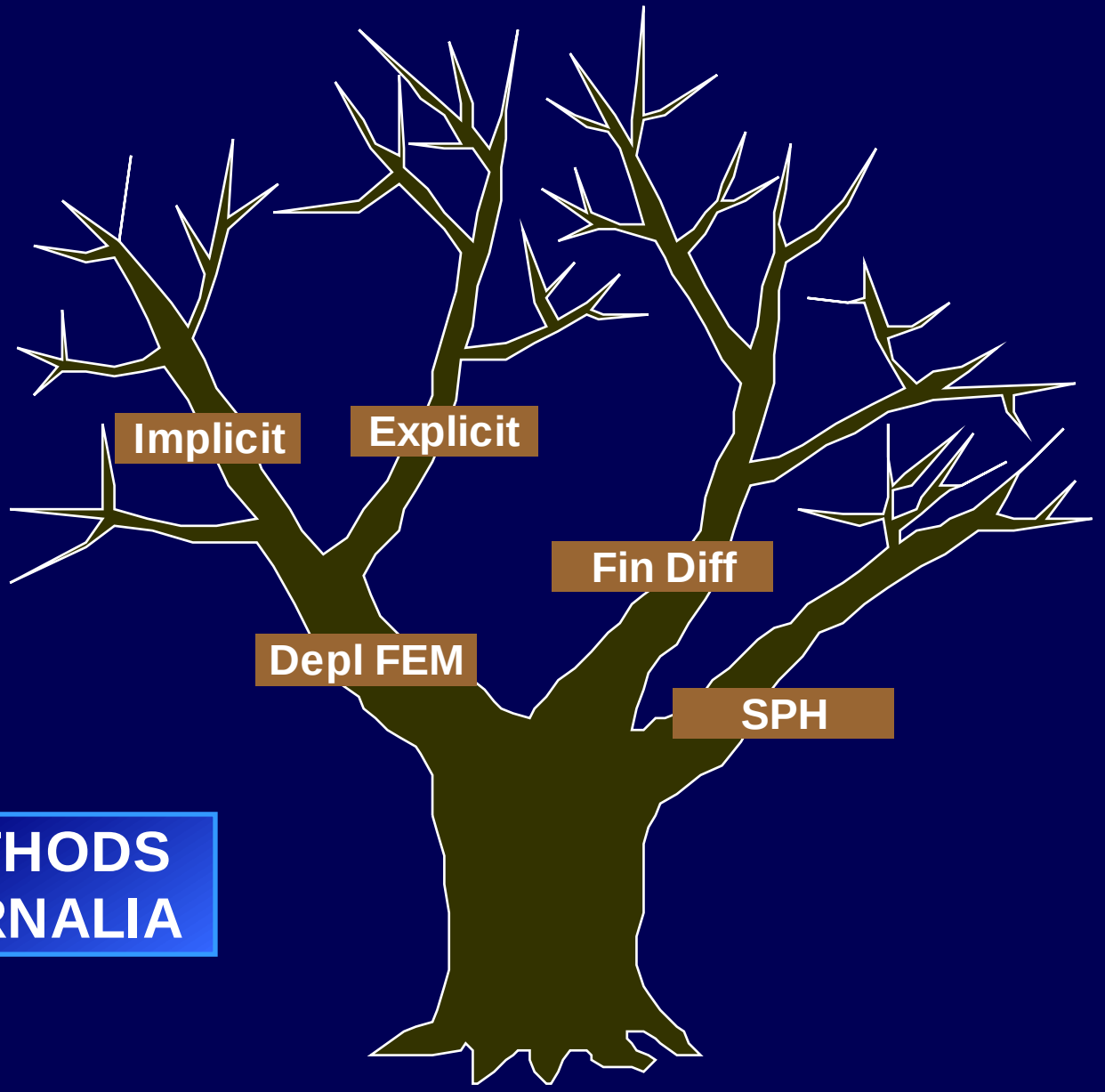
Theoretical foundations



Theoretical foundations



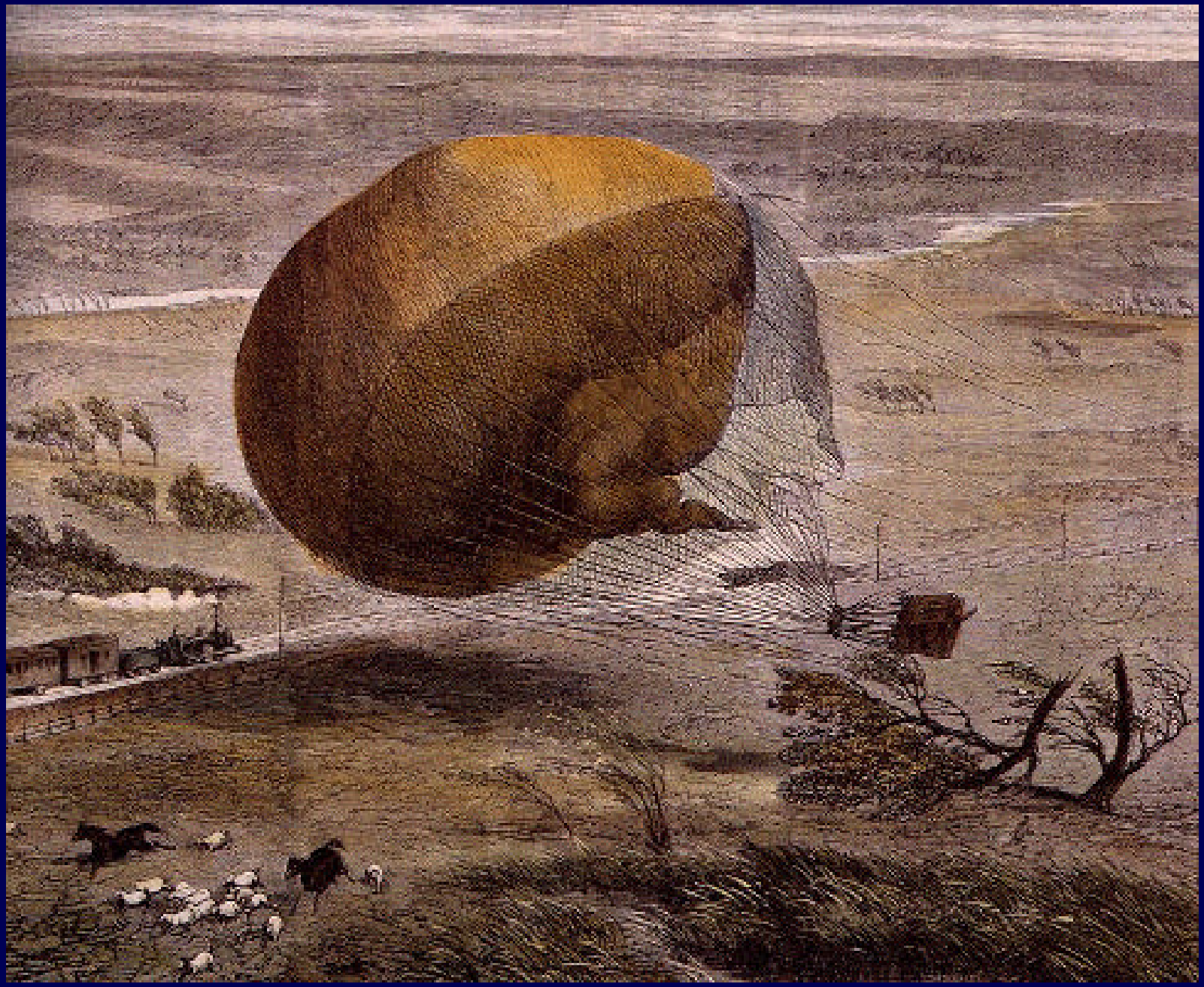
NUMERICAL METHODS DAILY PARAPHERNALIA

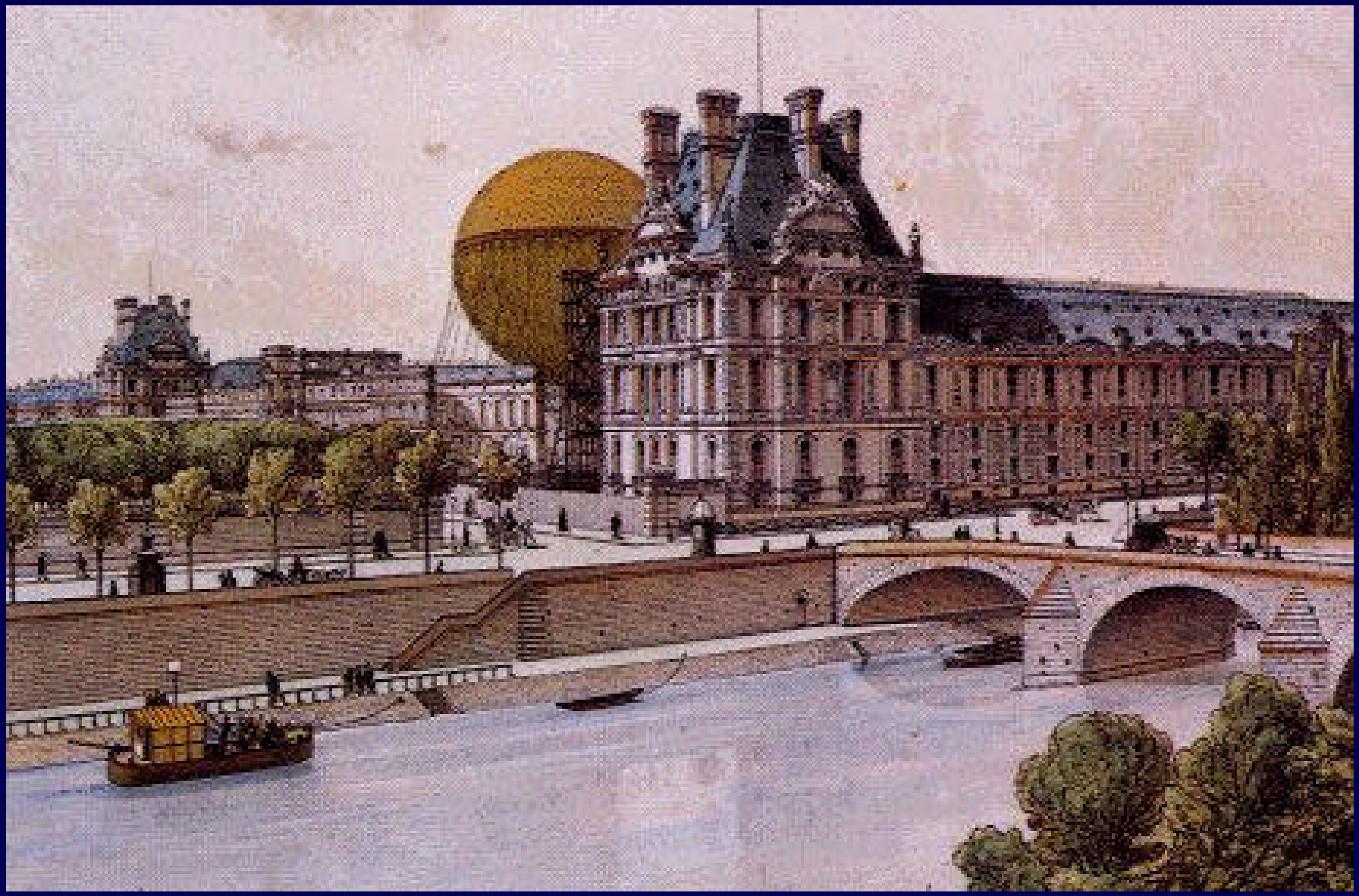


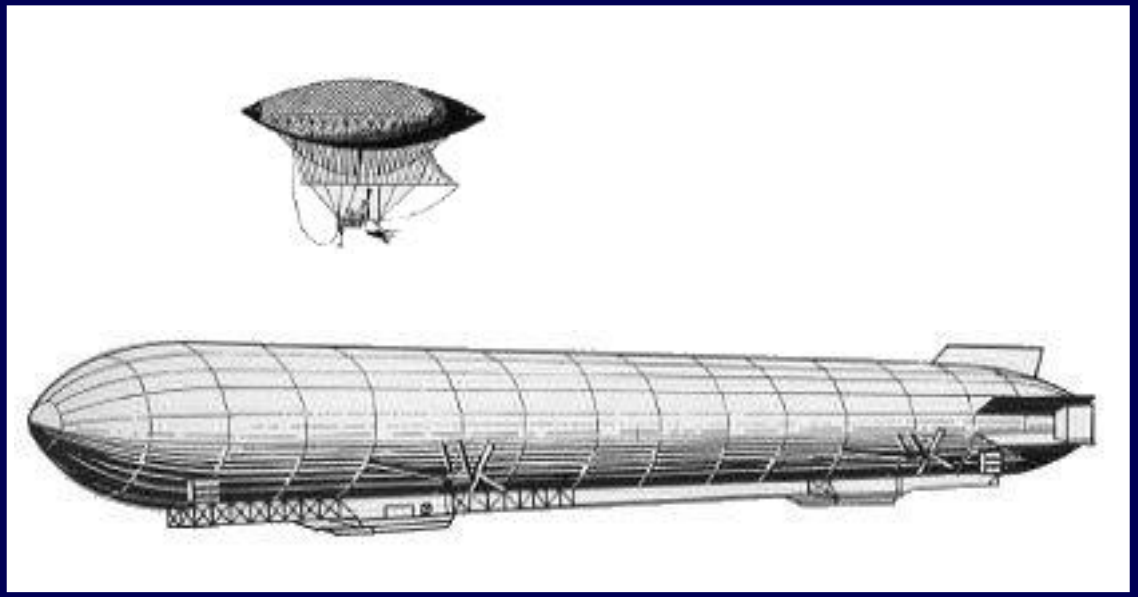
Dynamics in Aerospace

- Airships
- Aircrafts
- Spacecrafts


LE GEANT





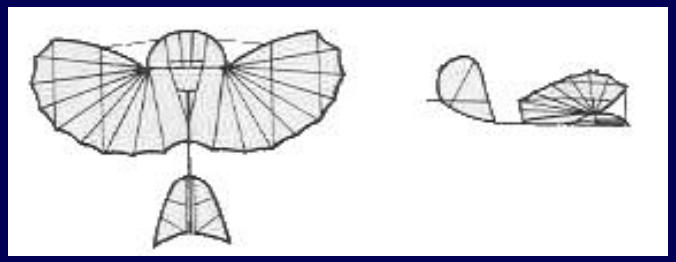


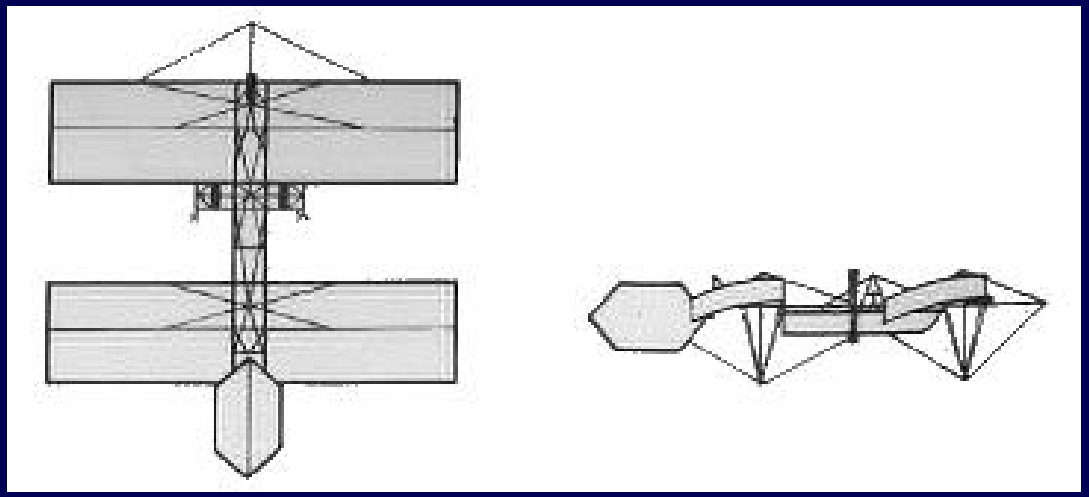
Structure : rods, beams, threads & sails

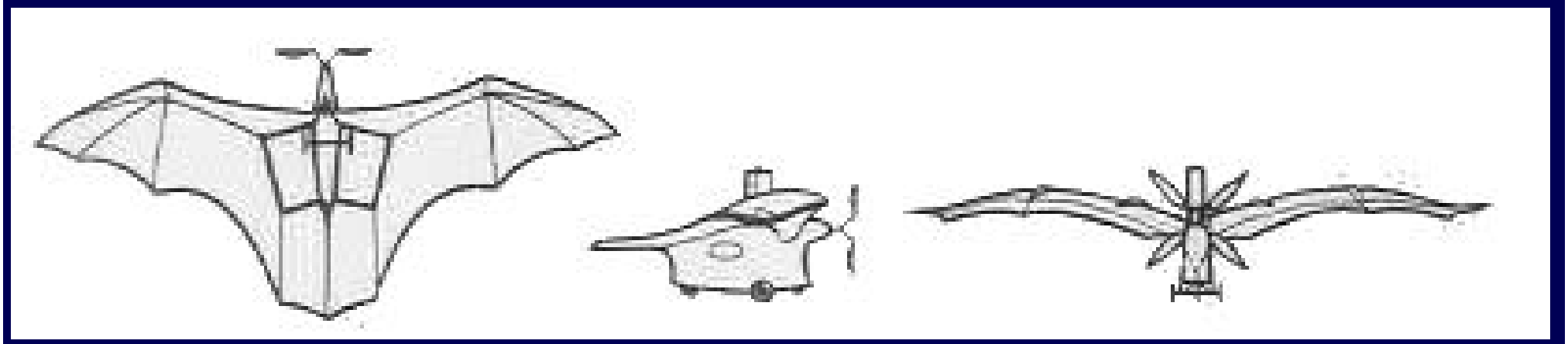
Non-développability :
- **Dynamic stability**
- **Command**

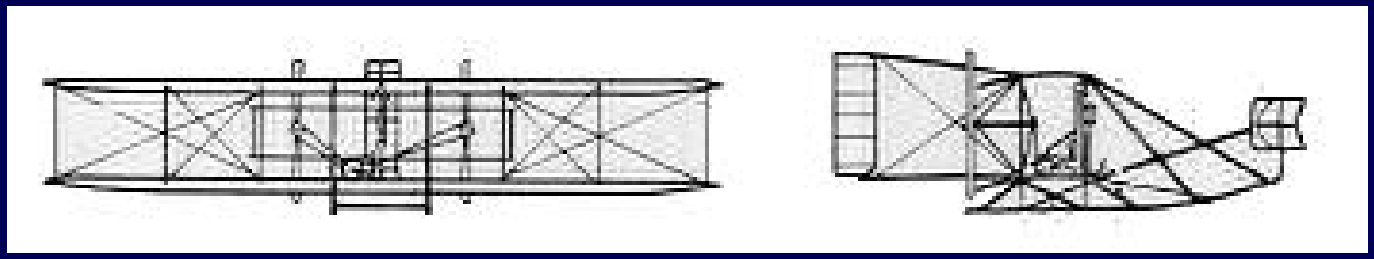
Dynamics in Aerospace

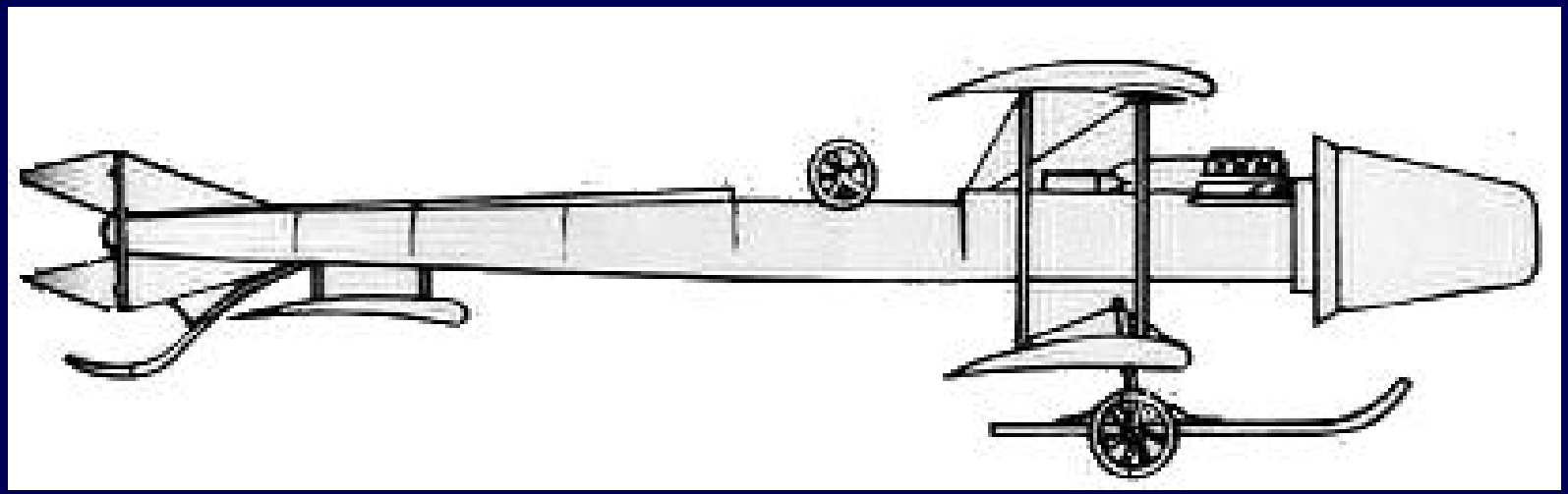
- Airships
- Aircrafts
- Spacecrafts







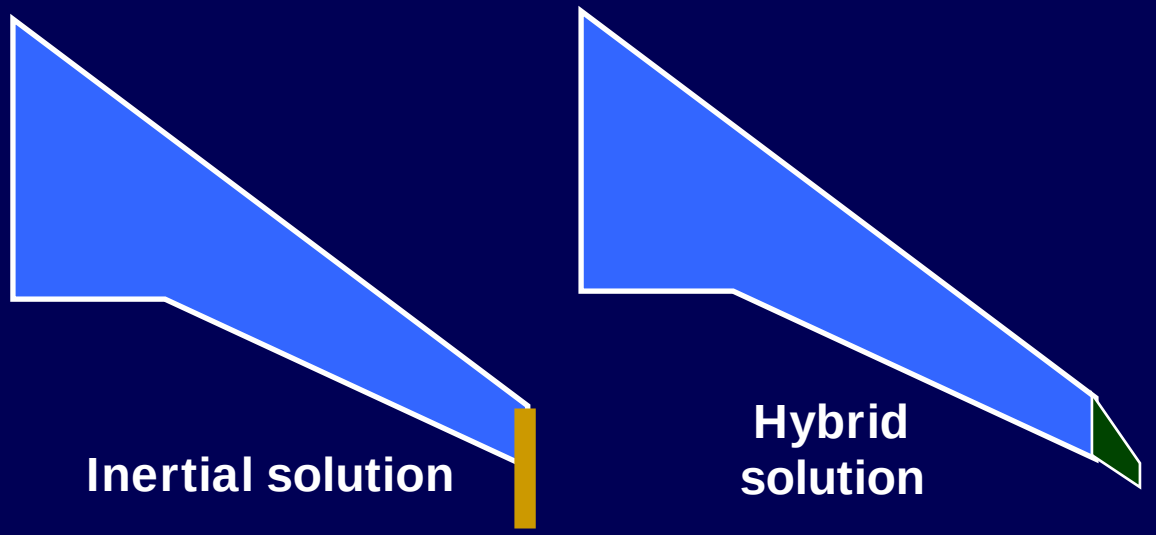




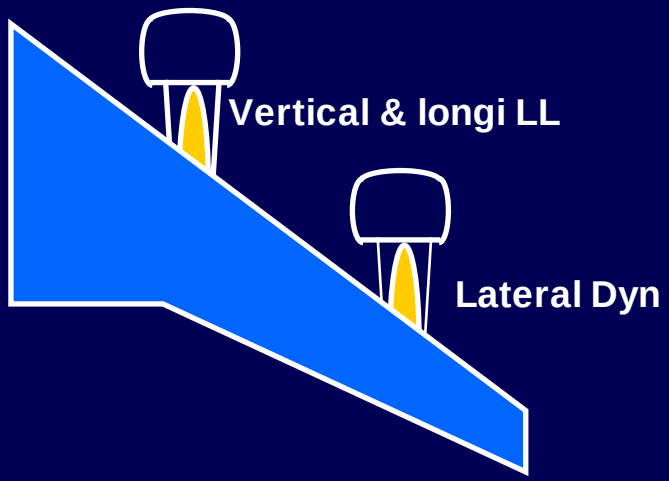

United States
NASA

Quasistatic Certification Loads - Dynamic Behavior - Vibrational Stability

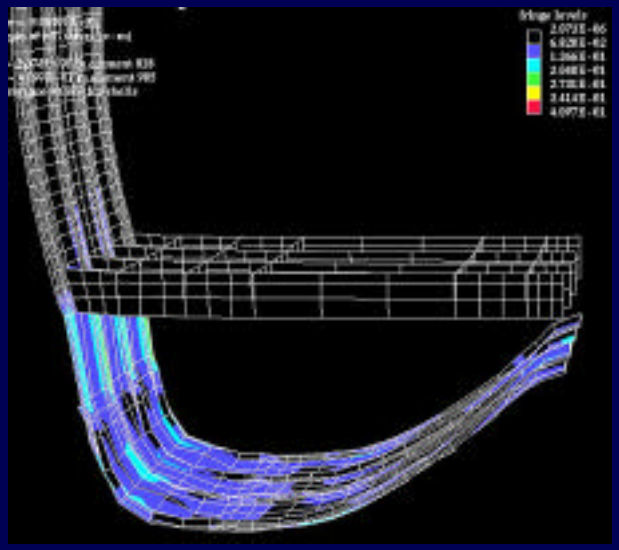
Flutter
Dynamic Stability



Engine
Dynamic Sizing



Shock & Crashworthiness



- **Global crash test / model**
- **Depressurization**
- **Global shock analysis (impact & ingestion, shock protection)**
- **Local material Damage Tolerance.**