Passivation with unknown fuel composition

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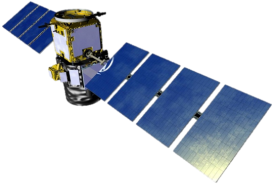
CALIPSO mission

Launched in 2006 and programmed to end in 2011
mission was extended until 2023

⇒ Time to anticipate **fluidic passivation** due in 2023

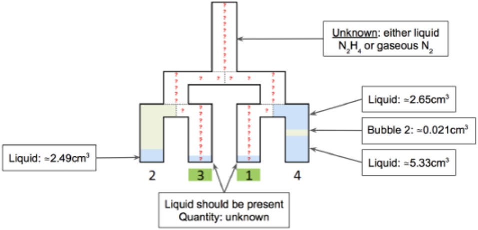
- Remove all of energy sources (liquid and gas)
- Preferably reduce time before natural reentry
- 4 maneuvers planned



Problem: EOL state of the tanks

Unknown fuel state and proportion in the tanks

⇒ Impossible to anticipate the thrust magnitude



Problematic:

How should the maneuver errors be modeled?

How will it affect the results?

What do we actually know?

Maneuver thrust can be liquid, gas or a mix of both

- If thrust is **100% liquid**: $\Delta V_{\text{liq}} = 0.14\,\text{m}\,\text{s}^{-1}$
- If thrust is **100% gas**: $\Delta V_{\text{gas}} = 0.012\,\text{m}\,\text{s}^{-1}$

Passivation: empty fuel from tanks

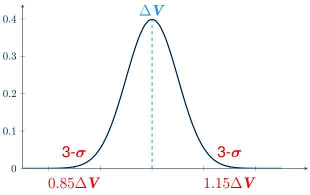
- Direction of maneuvers doesn't matter

  $\Rightarrow$ Prioritize **out-of-plane** maneuvers rather than tangential maneuvers

Maneuver magnitudes and uncertainties

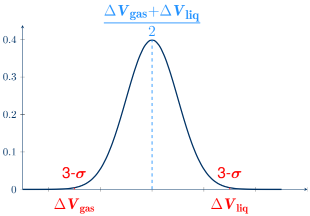
Anticipated fuel composition (Fig. 1)

- Normal law $\mathcal{N}(0, 5\%)$ with nominal thrust $\Delta \boldsymbol{V}_{\mathbf{gas}}$
- Normal law $\mathcal{N}(0, 5\%)$ with nominal thrust $\Delta \boldsymbol{V}_{\mathbf{liq}}$



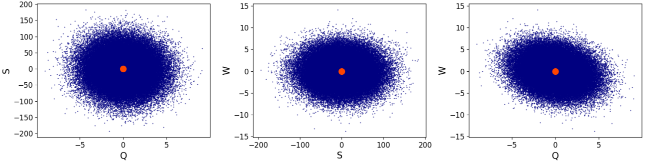
Random fuel composition

- Normal law $\mathcal{N}(0, 28.1\%)$ with nominal thrust $\frac{\Delta \boldsymbol{V}_{\mathbf{gas}}+\Delta \boldsymbol{V}_{\mathbf{liq}}}{2}$ (Fig. 2)
- Uniform law $\mathcal{U}(\Delta \boldsymbol{V}_{\mathbf{gas}}, \Delta \boldsymbol{V}_{\mathbf{liq}})$

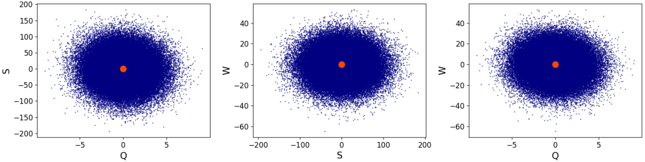


ANTICIPATED FUEL COMPOSITION

Normal law $\mathcal{N}(0, 5\%)$ with nominal thrust $\Delta \boldsymbol{V}_{\mathbf{gas}}$ or $\Delta \boldsymbol{V}_{\mathbf{liq}}$



Nominal thrust $\Delta \boldsymbol{V}_{\mathbf{gas}}$

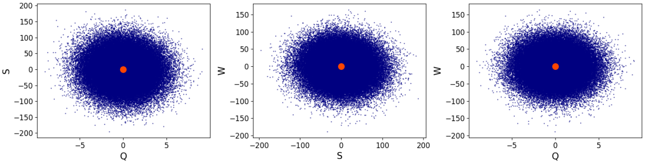


Nominal thrust $\Delta \boldsymbol{V}_{\mathbf{liq}}$

Gaussian uncertainties after 24h propagation

RANDOM FUEL COMPOSITION

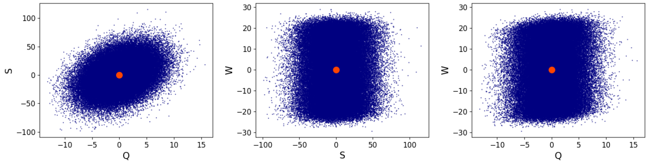
Normal law $\mathcal{N}(0, 28.1\%)$ with nominal thrust $\frac{\Delta V_{\text{gas}} + \Delta V_{\text{liq}}}{2}$



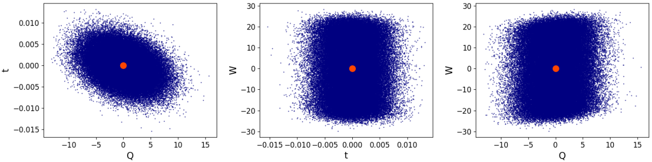
Gaussian uncertainties after 24h propagation

RANDOM FUEL COMPOSITION

Uniform law $\mathcal{U}(\Delta \boldsymbol{V}_{\mathbf{gas}}, \Delta \boldsymbol{V}_{\mathbf{liq}})$



Representation in QSW

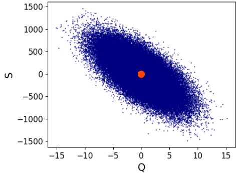


Representation in QtW

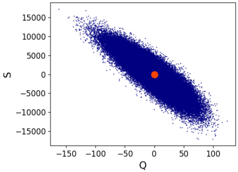
QtW useless, no alternative method for risk computation

IF MANEUVERS WERE TANGENTIAL?

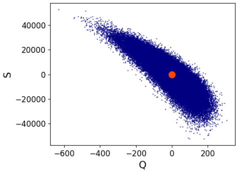
Normal law $\mathcal{N}(0, 5\%)$ with nominal thrust $\Delta \boldsymbol{V}_{\textbf{gas}} \rightarrow$ ✓



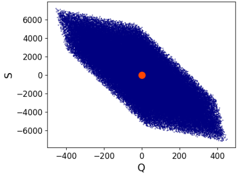
Normal law $\mathcal{N}(0, 5\%)$ with nominal thrust $\Delta \boldsymbol{V}_{\textbf{liq}} \rightarrow$ **QtW**



Normal law $\mathcal{N}(0, 28.1\%)$ with nominal thrust $\frac{\Delta \boldsymbol{V}_{\textbf{gas}} + \Delta \boldsymbol{V}_{\textbf{liq}}}{2} \rightarrow$ **QtW**



Uniform law $\mathcal{U}(\Delta \boldsymbol{V}_{\textbf{gas}}, \Delta \boldsymbol{V}_{\textbf{liq}}) \rightarrow$ **??**



Necessary to have *testing* maneuvers to estimate the composition of thrust

Thrust shows a tendency of **normal distribution** around ΔV_{gas}, ΔV_{liq} or $\frac{\Delta V_{\text{gas}}+\Delta V_{\text{liq}}}{2}$

- Traditional method or QtW coordinates when necessary ✓

Random thrust in $[\Delta V_{\text{gas}}, \Delta V_{\text{liq}}]$

- No method available for risk computation ✗

Thank you for your attention

(last time)