Hydraulic System Simulation

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Hydraulic system task context

- ✓ **Objectives of the task**
  - **Increase the level of simulation in hydraulic system design**
  - **Increase hydraulic system simulation fidelity to contribute to design cycle and costs reduction**

- ✓ **Hydraulic System simulation contributes to the renewal of the systems development process by providing to flight controls and handling qualities teams the most realistic hydraulic model at the earliest**

Hydraulic system overview

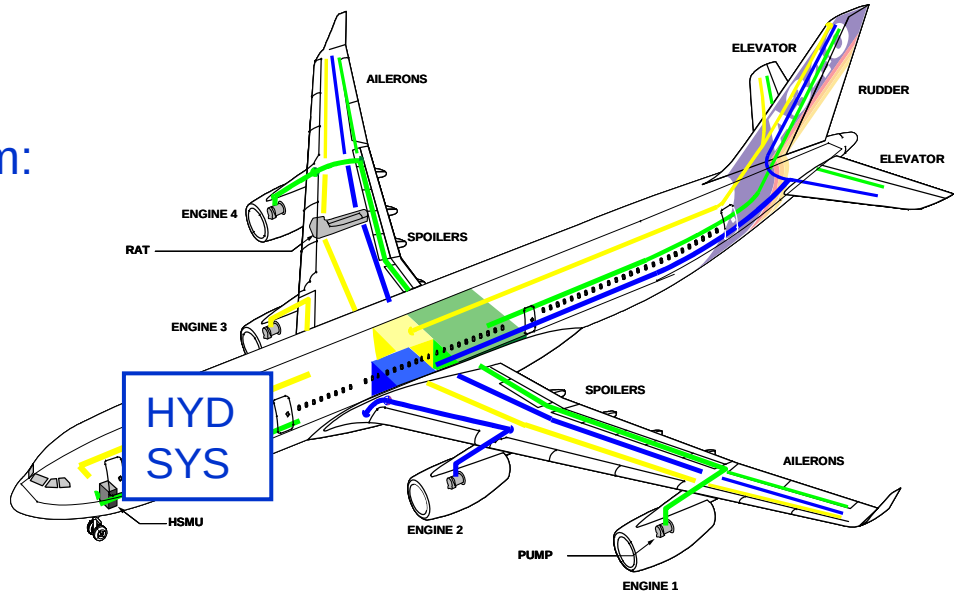
✓ Basic function of Aircraft Hydraulic system: to provide required power to hydraulic consumers which are (mainly):

- Flight control surfaces (ailerons, elevator, rudder, spoilers, flaps…)
- Landing gear systems (extension and retraction, braking, steering…)
- Cargo doors, thrust reversers…

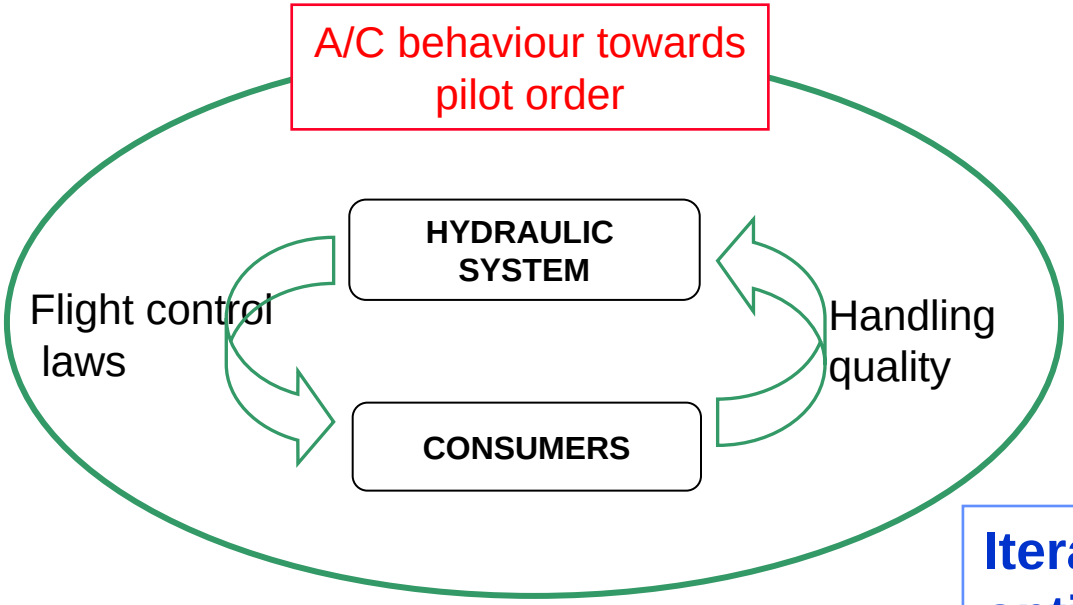
✓ Main components of Hydraulic system:

- Pumps
- Valves
- Filters
- Reservoir
- Indicating devices
- Pipes and fittings…

Hydraulic Reservoir



Hydraulic system simulation



Iterative work for sizing and optimisation of:

- Hydraulic system
- Hydraulic consumers
- Flight control laws

Hydraulic task scenarios

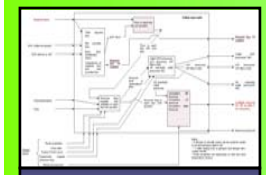
SCENARIO 1

PRE-DESIGN MODEL

✓System level
✓Flight control laws and handling quality specialists use

Scenario completed

Tool: SCADE



Pre-design model

✓Available early
✓Real time
✓Integration in flight control simulation platforms (multi-systems)
✓Base for more complete models (later)

=>Improve flight control tests cases fidelity
=>Reduce iterations, and iterations time between hydraulic system and flight control laws / handling quality
=>Earlier optimisation of hydraulic generation

Realistic but nevertheless simple, as required

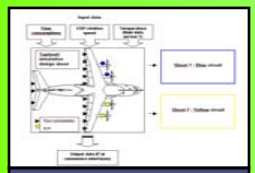
SCENARIO 2

DETAILED MODEL

✓System level
✓Hyd system specialists use

On-going work

Tool: SABER



Detailed model

✓Non real time
✓Physical dynamic modelling
✓Stand-alone simulation
✓Coupled simulation with flight control simulation platform (not integrated in multi-systems simulation platforms)

=>Improve hydraulic model fidelity
=>Hydraulic system detailed performances and behaviour status
=>Earlier system verification and validation
=>Reduce Iron Bird and flight tests

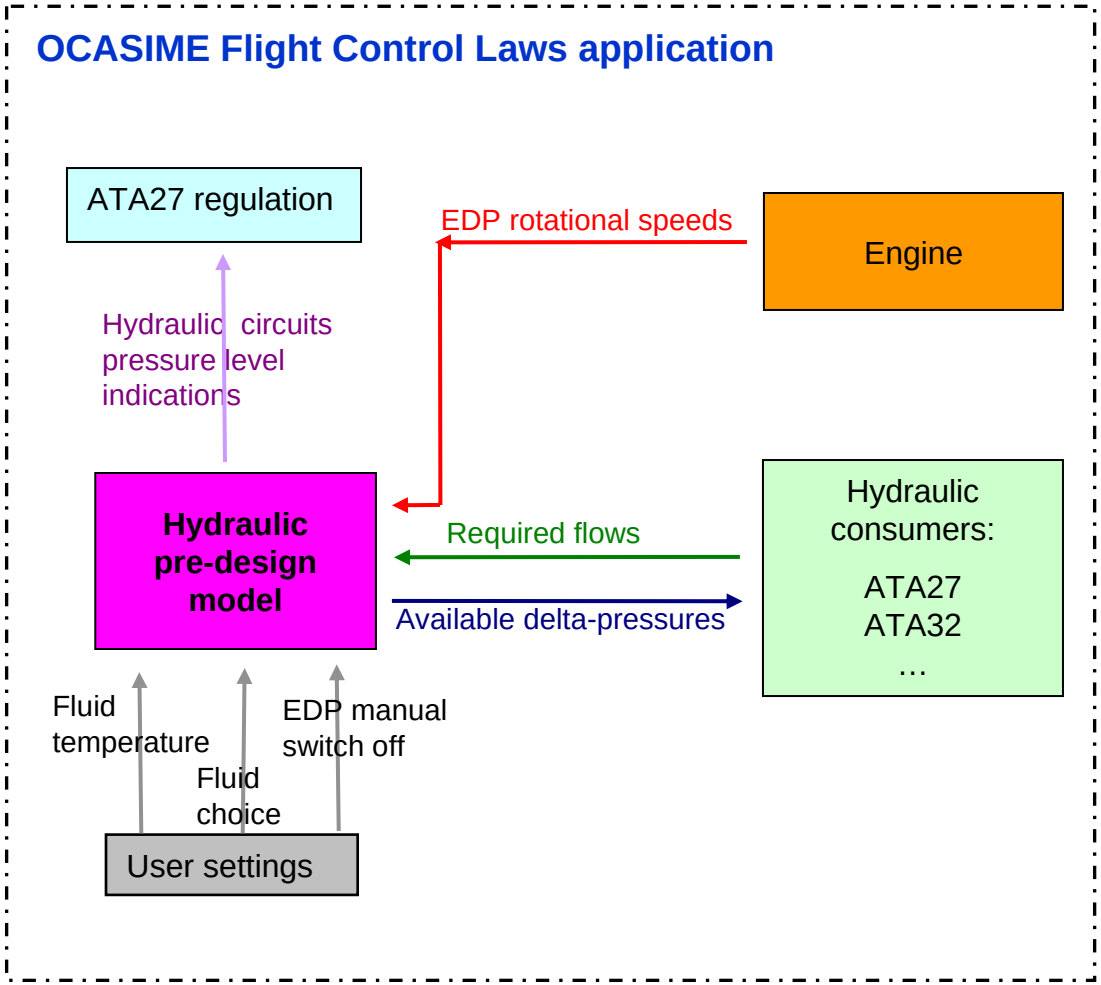
More accurate

Zoom on scenario 1: hydraulic pre-design model

- **Pre-design model integration and interfaces**

OCASIME

OCASIME:
- ✓ desk top simulator workshop
- ✓ piloting function and virtual cockpit



Zoom on scenario 1: hydraulic pre-design model

Main characteristics of the pre-design model (model content)

✓ Improvement of hydraulic elements modelling (manifolds, filters, priority-valves pressure drop)
✓ Choice between two types of fluids (high or low density)
✓ Choice of the fluid temperature (1)
✓ Priority valves (2) and low pressure switches logics modelled
✓ Engine driven pumps model using static curves (pressure / flow). Overflow functioning part represented (3)
✓ Engine driven pumps switch off possible (apart from engine state) (4)

=> (1) / (2) / (3) / (4) → Simulations with insufficient hydraulic power possible (impact analysis)

✓ Overflow functioning detection function
✓ Interfaces compatibility with consumers models evolutions

Zoom on scenario 1: hydraulic pre-design model

Pre-design model other advantages:

✓ Integration into the complete hydraulic system model, including monitoring and regulation functions and several accuracy levels

- Scade (language commonality)
- Development rules compatible with Airbus official procedure
- Upstream work with other simulation developers allowing:
  - to take benefit from previous aircraft simulation experience
  - to build compatible cross-models architectures

✓ Hydraulic models library creation (sub-parts “ready for use” for new aircraft predesign model)

- Fluid data
- Fluid properties calculation (fluid data use)
- EDP
- Manifold
- Priority valve
- Low pressure switch
- Pressure drops calculations (linear, singular, total), pressures calculation
- Consumers pressures handling for display

Zoom on scenario 1: hydraulic pre-design model

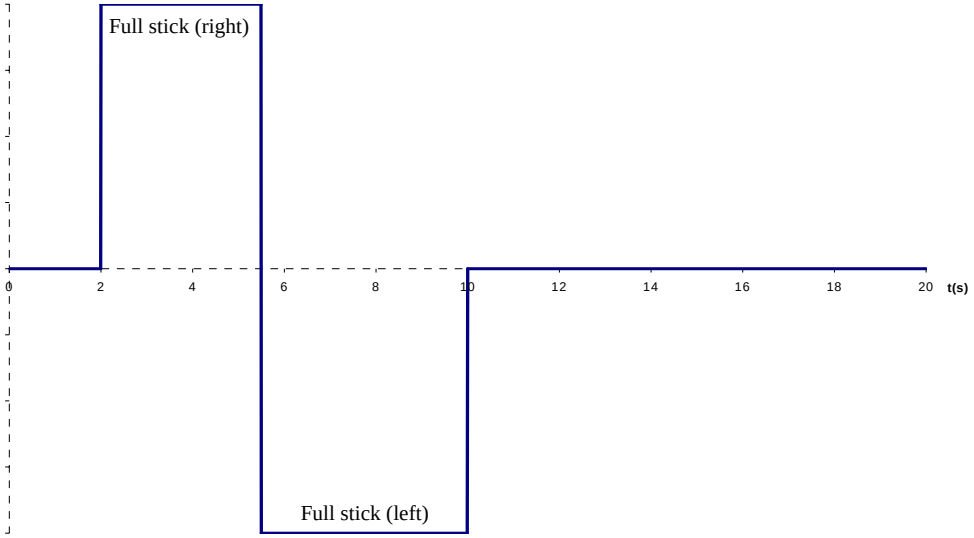
Pre-design model benefices illustration

✓ **Context:** for comparison purpose 2 types of simulations run on Ocasime laws platform:

- with hydraulic pre-design model
- without hydraulic pre-design model: pre-design model outputs disconnected and replaced by constant “required minimum delta-pressures”

[Definition: consumer required minimum delta-pressure = minimum delta-pressure determined for consumer sizing point and considered as minimum target for hydraulic system performances]

✓ **Flight control order (theoretical side-stick order)**

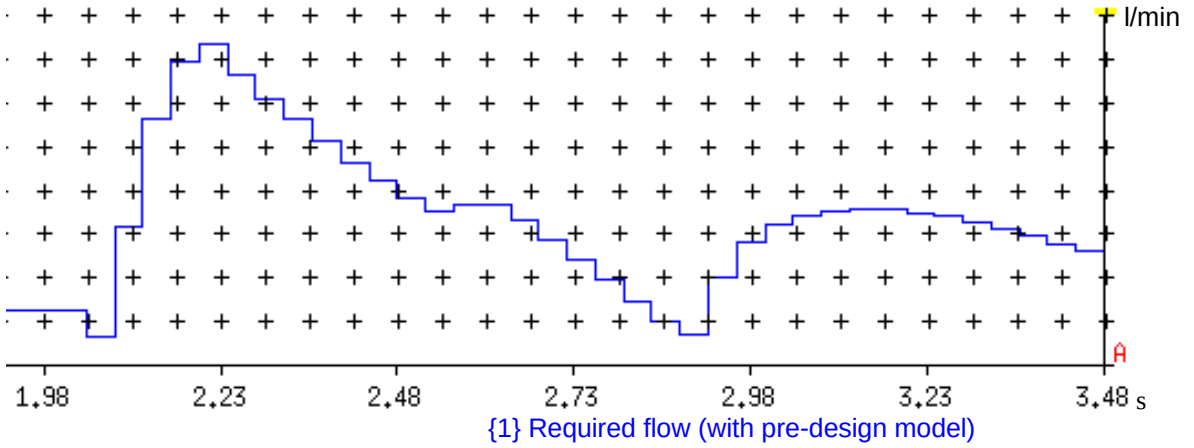


Zoom on scenario 1: hydraulic pre-design model

Pre-design model benefices illustration: case 1

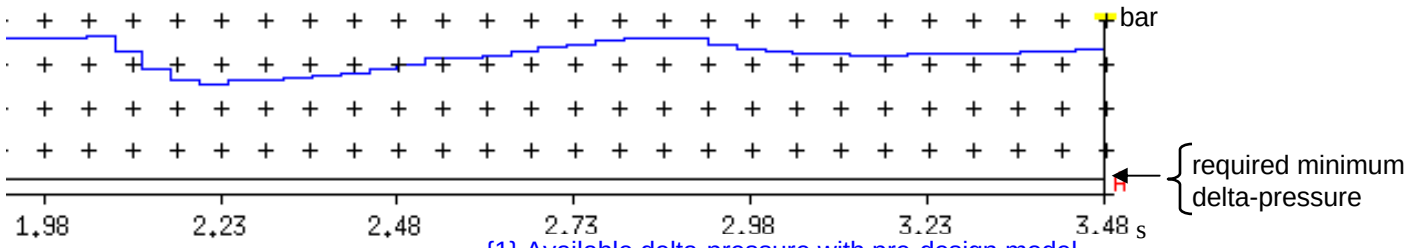
- ✓ Conditions: low fluid temperature, all pumps running
- ✓ Simulation results: Aileron performance: comparison between "with…" or "without pre-design model'

Aileron flow



{1} Required flow (with pre-design model)

Aileron available delta-pressure



{1} Available delta-pressure with pre-design model
{2} Available delta-pressure without pre-design model

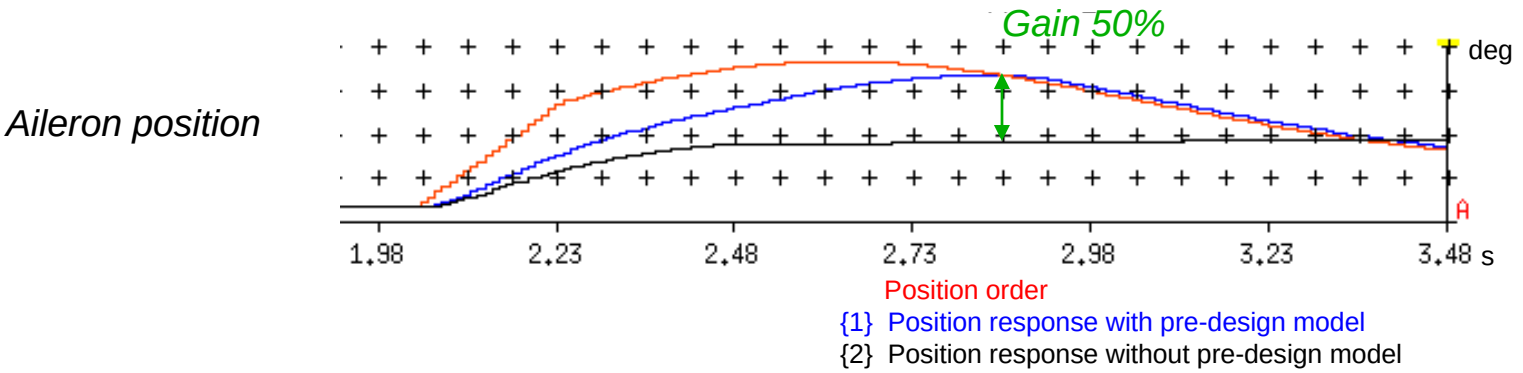
=> With pre-design model: more available pressure (in that case)

Zoom on scenario 1: hydraulic pre-design model

Pre-design model benefices illustration: case 1 (continuation)

✓ Simulation results:

- Aileron performance: comparison between "with…" or "without pre-design model" (continuation)



⇒ Position more realistic with pre-design model. In this case position reached is closer to the order.

⇒ Maximal position gain observed: around 50%

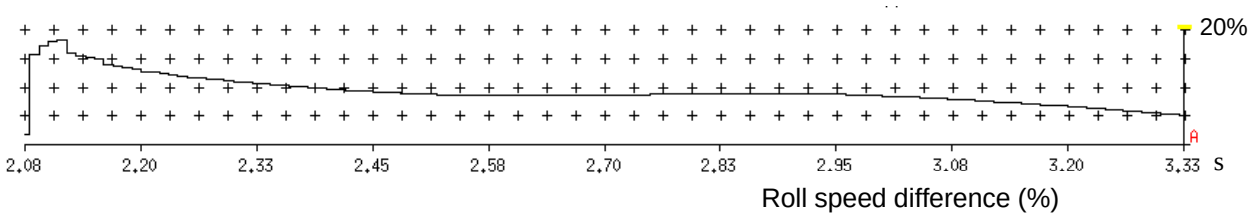
(Definition: position gain = ({1}–{2}) / position order * 100)

Zoom on scenario 1: hydraulic pre-design model

Pre-design model benefices illustration: case 1 (continuation)

✓ Simulation results:

- Roll speed: comparison between "with…" or "without pre-design model"



=> Maximal roll speed gain observed: around 16% (at beginning of motion)

(Definition: roll speed gain = absolute value [({1}–{2})/{1}] * 100, where {1} is the roll speed with pre-design model and {2} is the roll speed without pre-design model)

✓ Conclusion: Case 1 illustrates how pre-design model could be used to reduce:

- margins on (over)sizing of actuators or hydraulic system
- aircraft weight

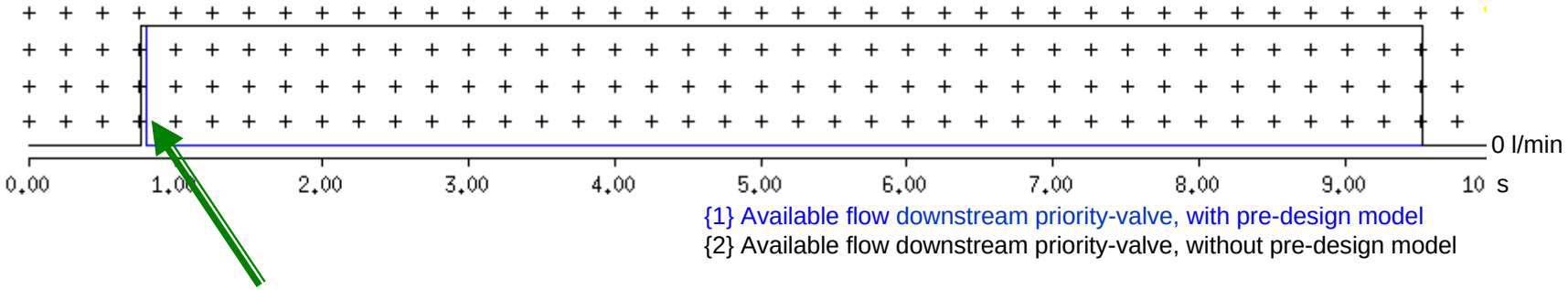
Zoom on scenario 1: hydraulic pre-design model

Pre-design model benefices illustration: case 2

✓ Conditions: low fluid temperature, 1 pump off among the 2 available, additional high flow requests from flaps motor and from one consumer downstream priority-valve

✓ Simulation results: priority-valve functioning: comparison between "with…" or "without pre-design model"

Available flow for consumers downstream priority-valve



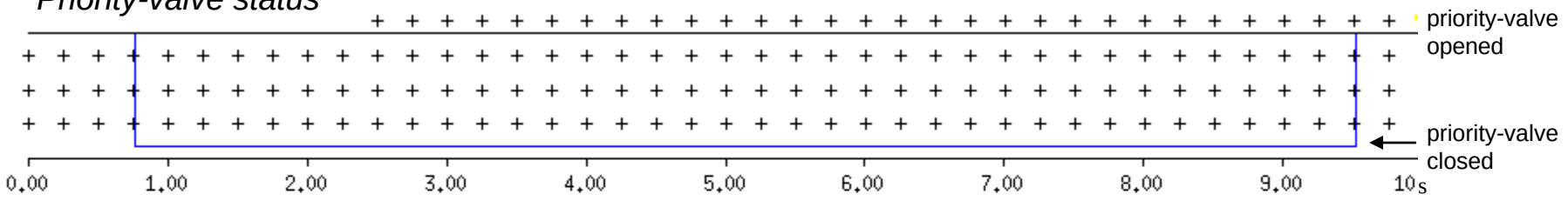
=> Priority function activated: flow supply interrupted for consumer downstream priority-valve

Zoom on scenario 1: hydraulic pre-design model

Pre-design model benefices illustration: case 2 (continuation)

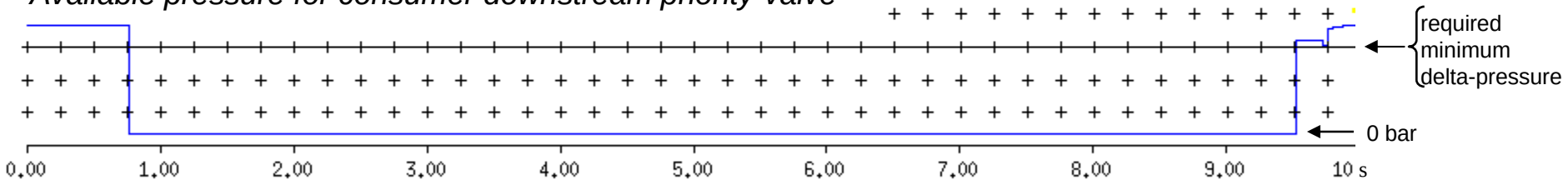
✓ Simulation results: priority-valve functioning: comparison between "with…" or "without pre-design model" (continuation)

Priority-valve status



{1} Priority-valve state with pre-design model
{2} Priority-valve state without pre-design model (virtual)

Available pressure for consumer downstream priority-valve



{1} Available delta-pressure downstream priority-valve, with pre-design model
{2} Available delta-pressure downstream priority-valve, without pre-design model

=> Priority valve operating is a new simulated functionality.

Zoom on scenario 1: hydraulic pre-design model

Pre-design model other benefits (not illustrated):

✓ Pre-design model also allows to simulate cases where flight control surfaces answers are overestimated:

- cases where model underlines insufficient hydraulic power (very low temperature for example)

✓ For such cases, as its answers are more realistic, pre-design model could underline tuning necessities (flight control laws, actuators or hydraulic system sizing, …) or flight limitations.

Hydraulic task: conclusion

✓ Hydraulic task is integrated with Virtual Aircraft contribution.

✓ Hydraulic pre-design model is innovative because it helps to improve the integration of hydraulic system in the pre-design phases of aircraft development:

- Increased model fidelity
- Model available early: method and library of sub-parts available

✓ Business benefits:

- Actuators, flight control surfaces and hydraulic system sizing mature more early; development time reduced
- Over-sizing margins reduction, weight gain

✓ The VIVACE contribution is already demonstrated and under exploitation:

- Pre-design model benefices illustration (cf. gain on flight control surfaces simulated position or on simulated A/C trajectory)

✓ VIVACE hydraulic task way forward:

- Scenario 2 “detailed model” will be presented at Forum 3.