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A propulsion simulation package in the Tool command language (Tcl)

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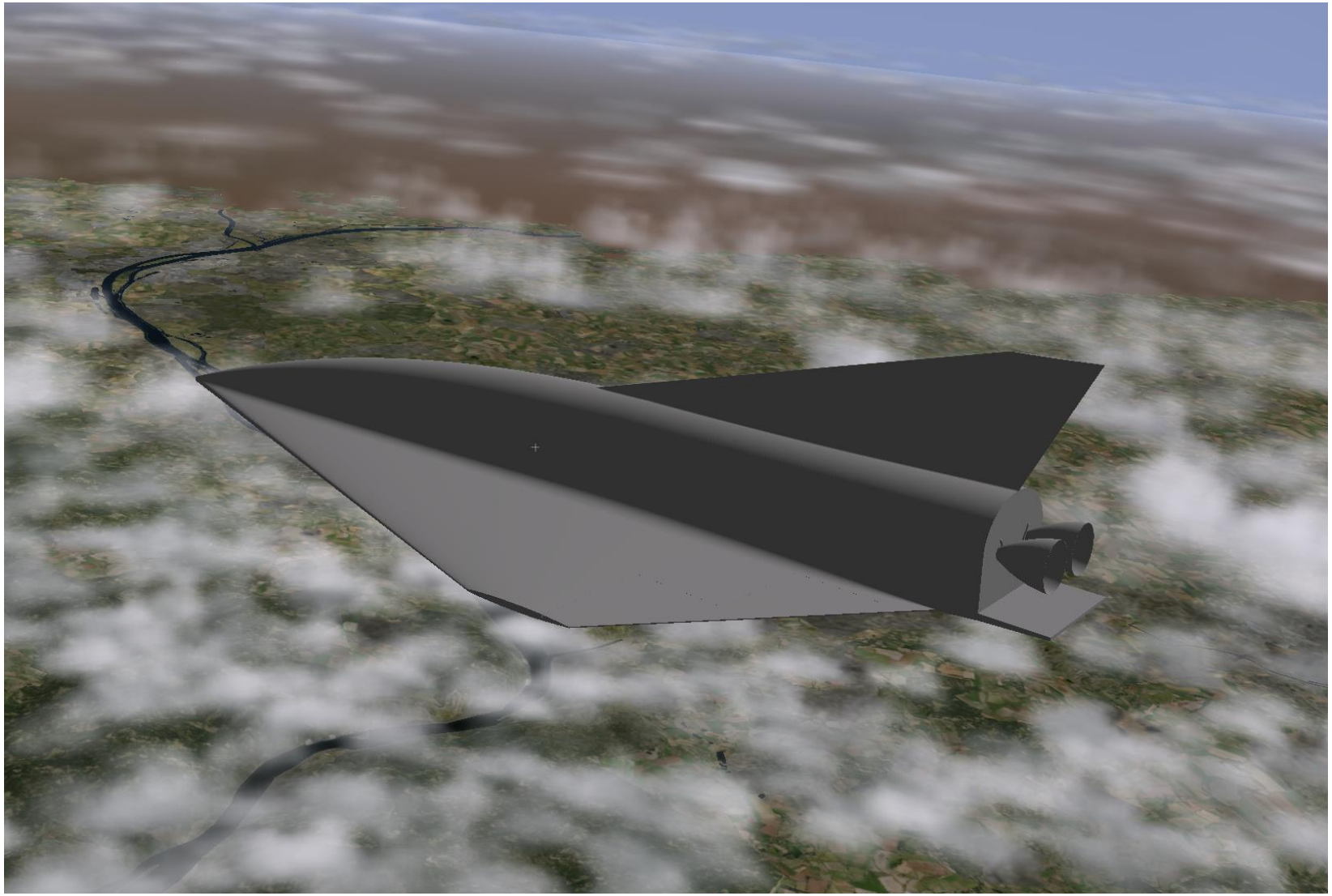
Overview

- **INTRO**
- **METHOD**
- **RESULTS**
- **CONCLUSION & OUTLOOK**

INTRO

SpaceLiner



DLR

INTRO

- **DLR's advanced concept for a suborbital, hypersonic, winged passenger transport**

- **thrustless flight dynamics model for the commercial flight simulation software "X-Plane" has been developed**

- **used in integration examinations of space traffic hypersonic gliding descent trajectories**

INTRO

Future analyses of rocket propelled flight phases:

→ need for the incorporation of a propulsion model

INTRO

Development requirements:

- as simple as possible with a minimum of development effort
- simple and flexible integration in the simulation environment
- use in a future system of systems context

METHOD

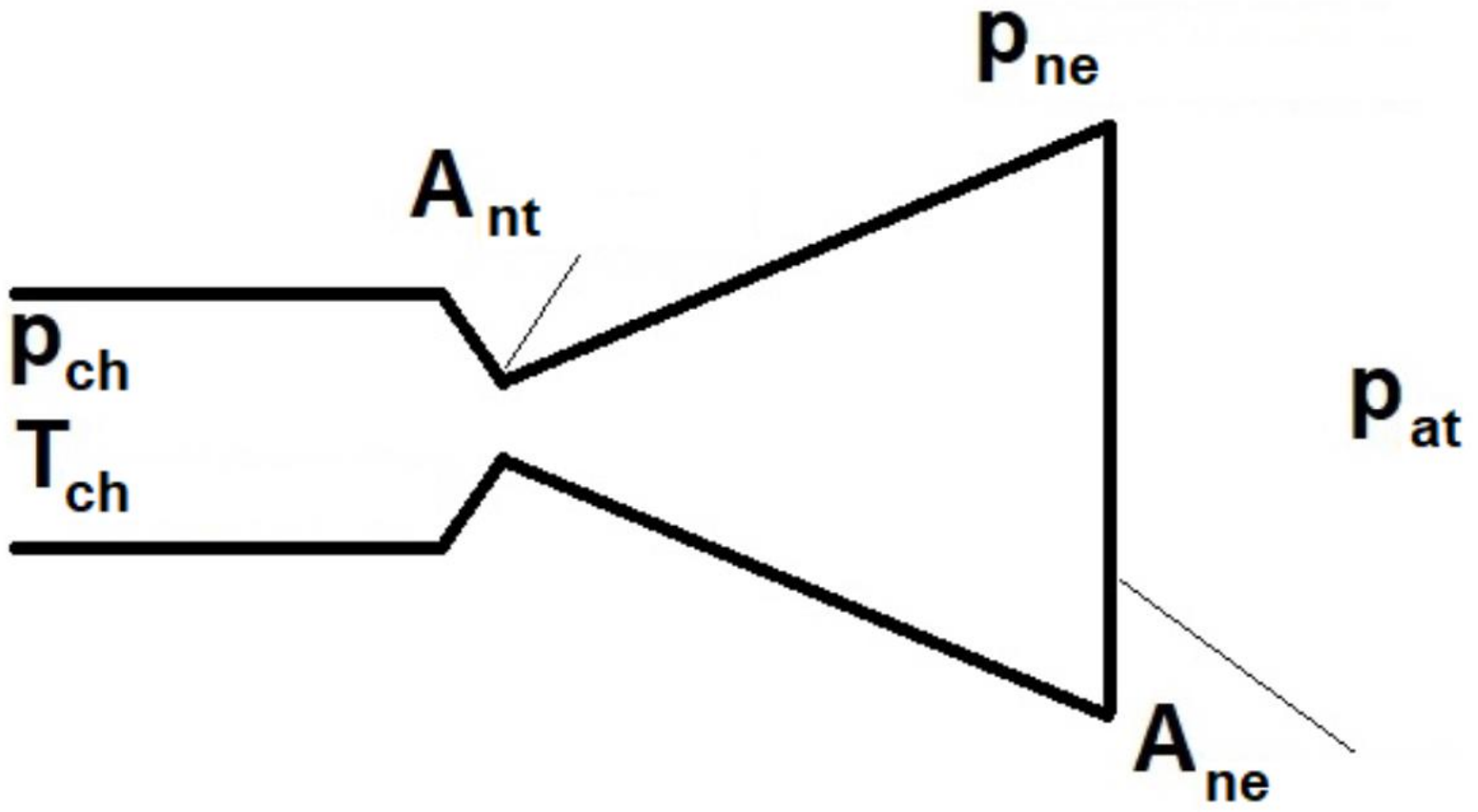
Realization as a Tool command language (Tcl) package

→ Why ???

- **general-purpose and rapid prototyping strengths of Tcl**
- **already developed X-Plane interface Tcl package**

METHOD

Configurable input parameters



METHOD

Fuel specific parameters:

- **universal gas constant**
- **molecular weight of the exhaust species**
- **isentropic exponent**

METHOD

Thrust:

$$F = \frac{dm}{dt} v_{ne} + A_{ne} (p_{ne} - p_{at})$$

Mass flow:

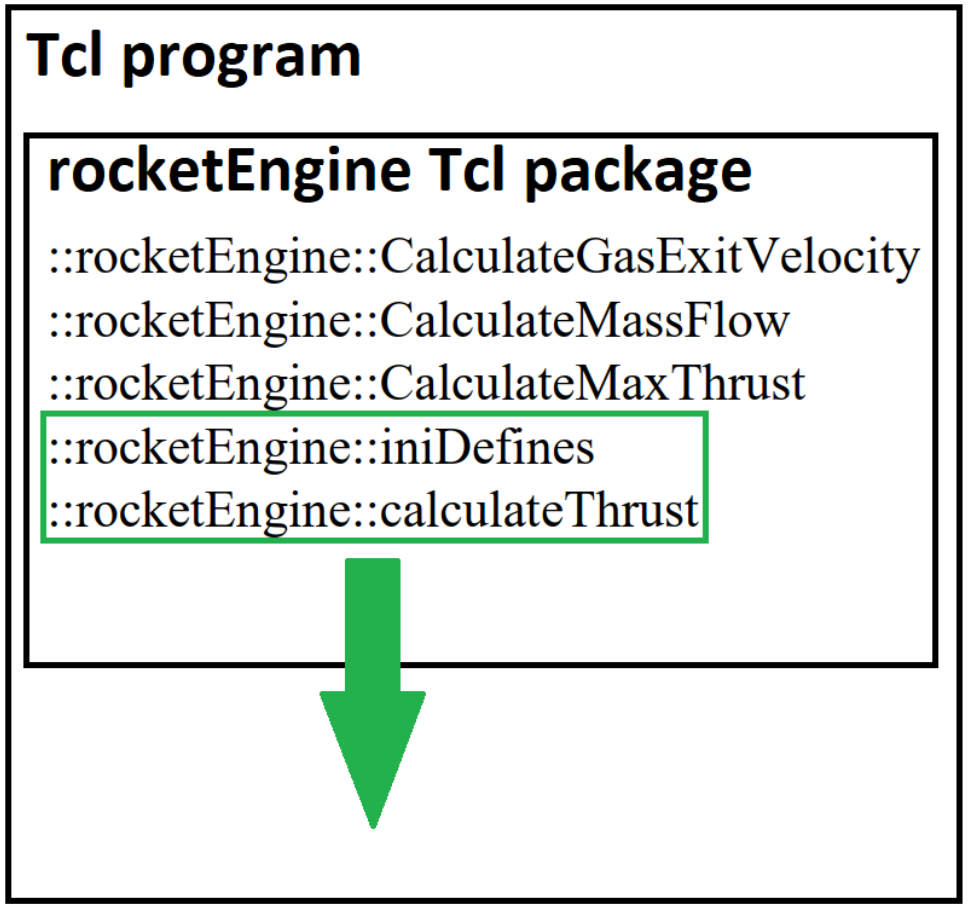
$$\frac{dm}{dt} = \frac{A_{nt} p_{ch} \gamma}{\sqrt{\frac{\gamma R T_{ch}}{M}}} \sqrt{\left(\frac{2}{\gamma+1}\right)^{\frac{\gamma+1}{\gamma-1}}}$$

gas velocity (nozzle exit):

$$v_{ne} = \sqrt{\frac{R T_{ch}}{M} \frac{2\gamma}{\gamma-1} \left[1 - \left(\frac{p_{ne}}{p_{ch}}\right)^{\frac{\gamma-1}{\gamma}}\right]}$$

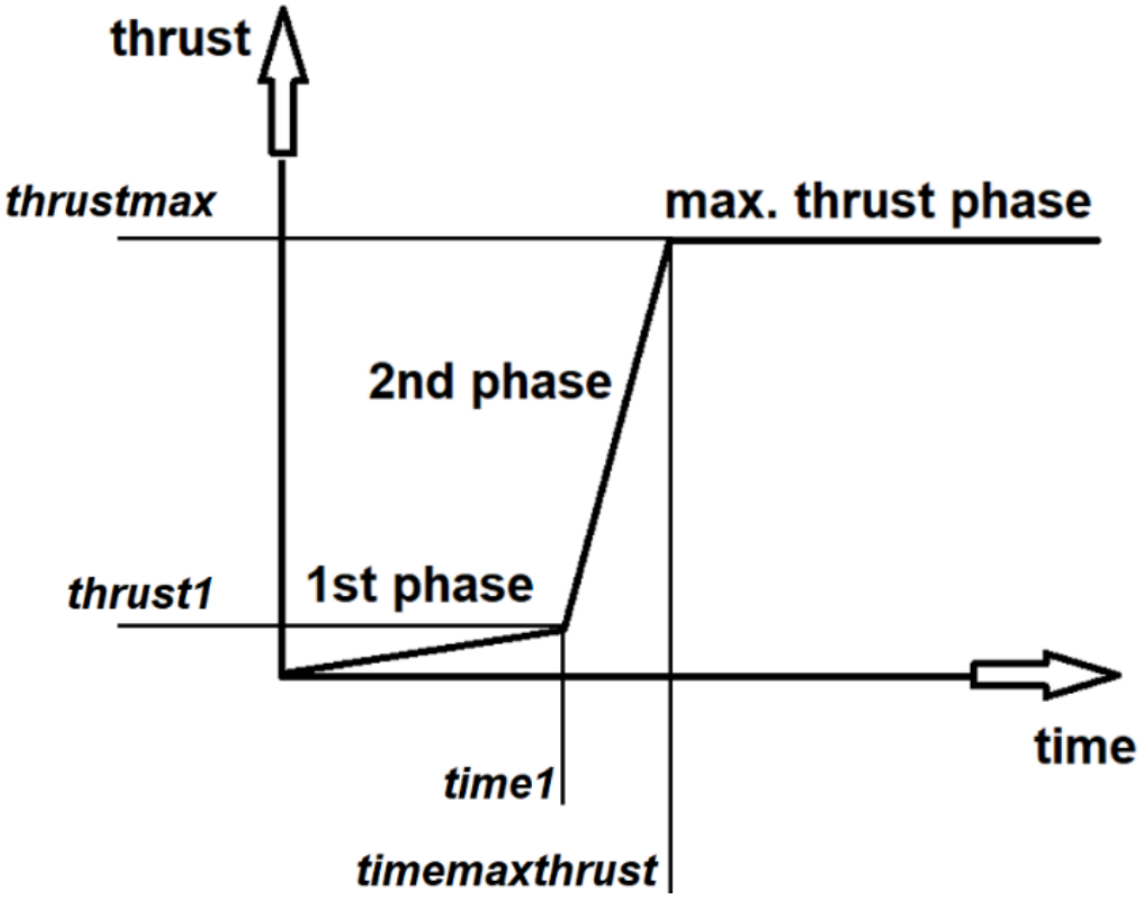
METHOD

Three internal and two external procedures:

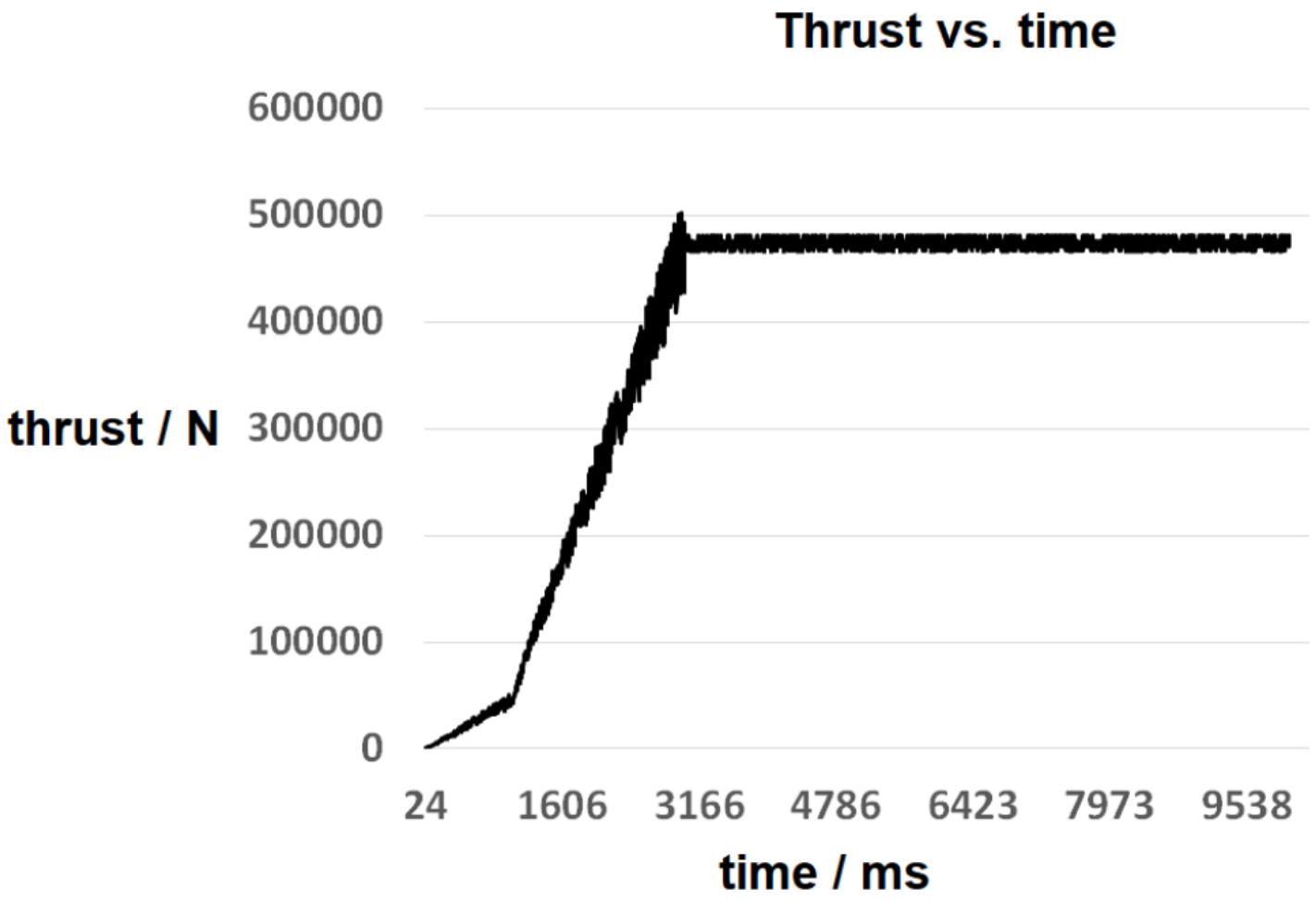


METHOD

Three configurable phases with random fluctuation parameters:

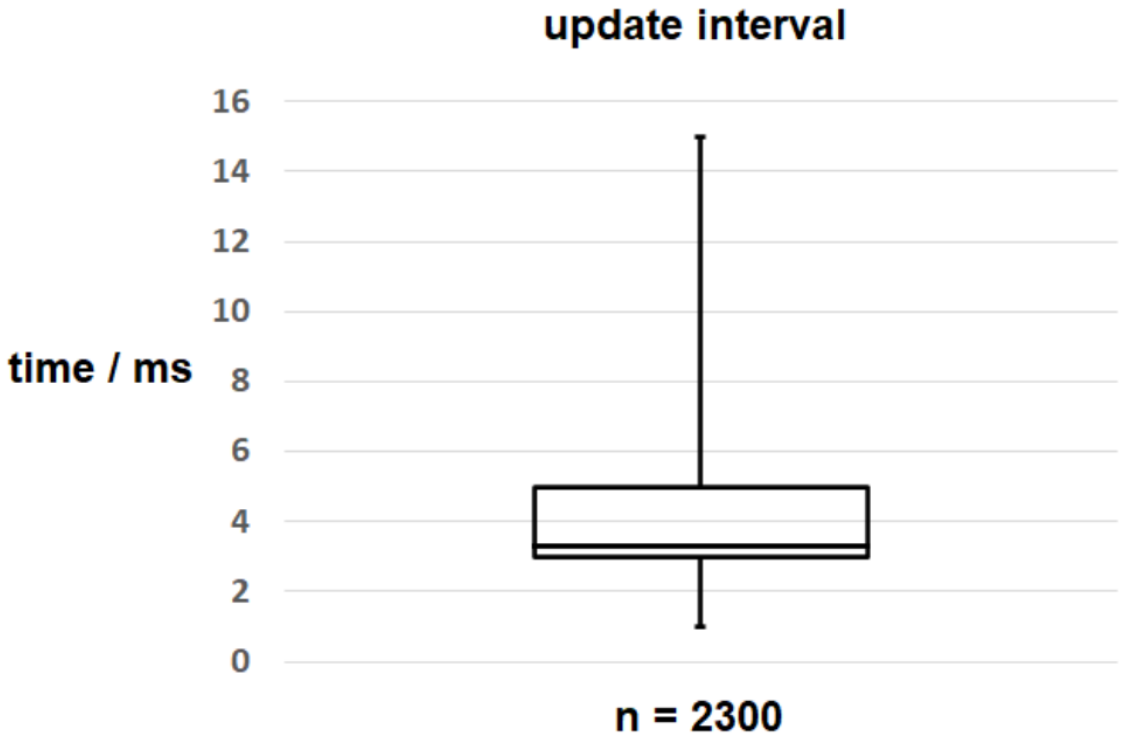


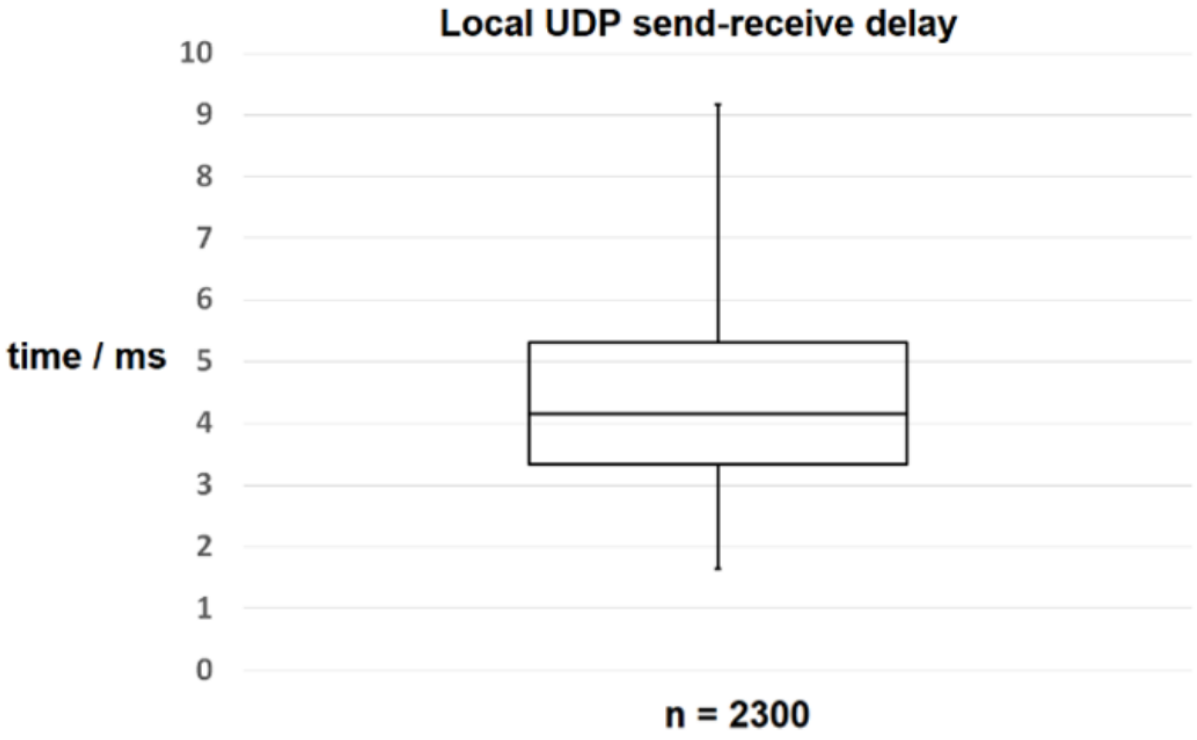
RESULTS



A_{nt}:	0.042 m^2
A_{ne}:	0.900 m^2
p_{ch}:	9720000 Pa
p_{ne}:	43008 Pa
p_{at}:	101325 Pa
T_{ch}:	3006 K
M:	22 kg/kmol
γ:	1.22
time1:	1 s
timemaxthrust:	3 s
fraction:	10 %
spread1:	15 %
spread2:	10 %
spread3:	2 %

RESULTS





worst-case execution time (WCET) and worst-case transmission time (WCTT): 15 ms + 9.1 ms = 24.1 ms

CONCLUSION & OUTLOOK

- **Tcl rocket engine propulsion package**
- **typical rocket engine design parameters as input values**
- **simple and flexible integration in the simulation environment with a soft real time performance of 50 Hz**

CONCLUSION & OUTLOOK

Future deployment of a rocket engine thrust federate in a distributed spacecraft simulation: