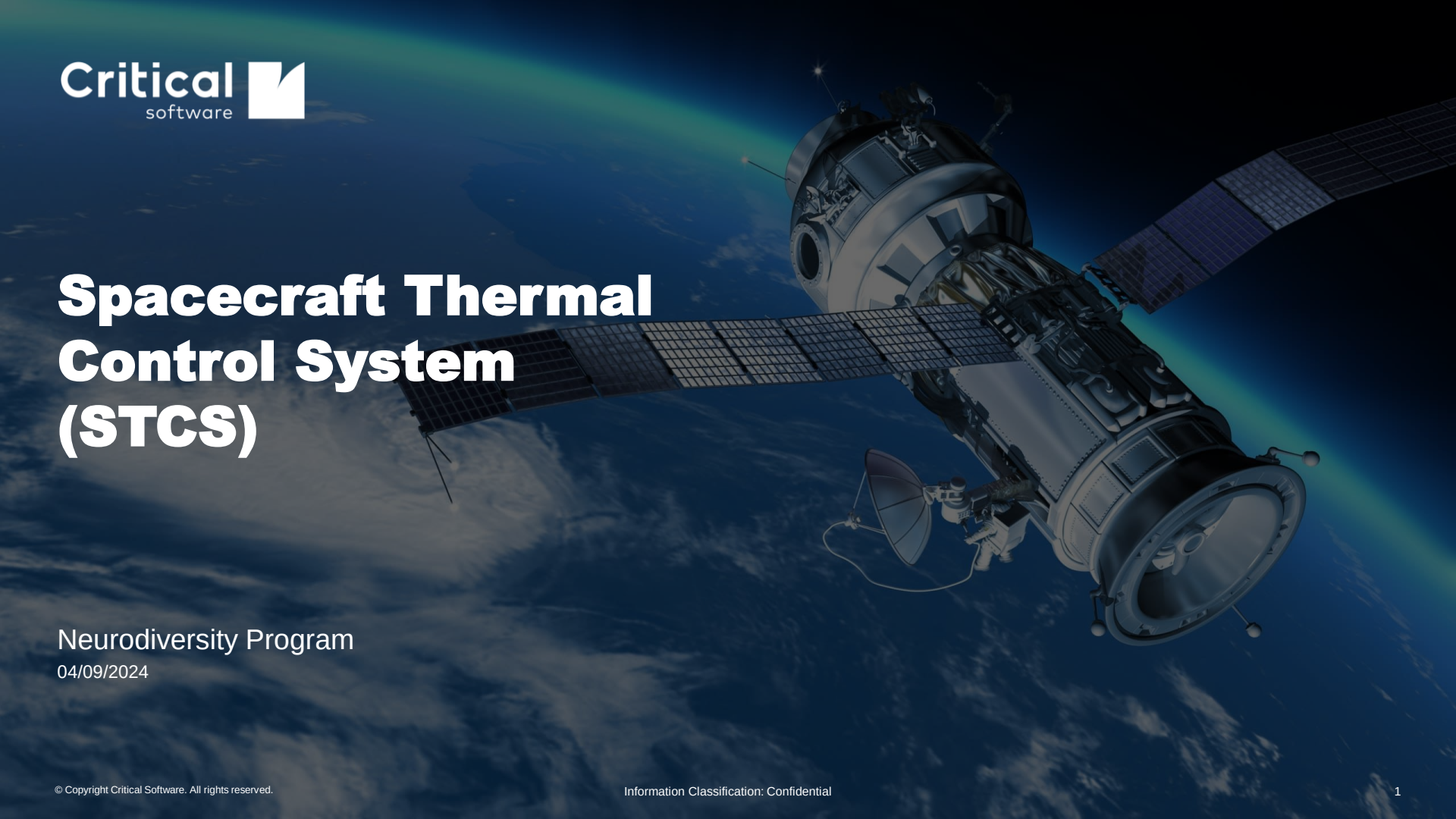


Spacecraft Thermal Control System (STCS)

Neurodiversity Program

04/09/2024

Summary

- The Fascination with Space
- Introduction to Satellites
- Space Environment
- Importance of Thermal Control
- Spacecraft Thermal Control System
- Tools and Technologies
- Conclusion
- Q&A

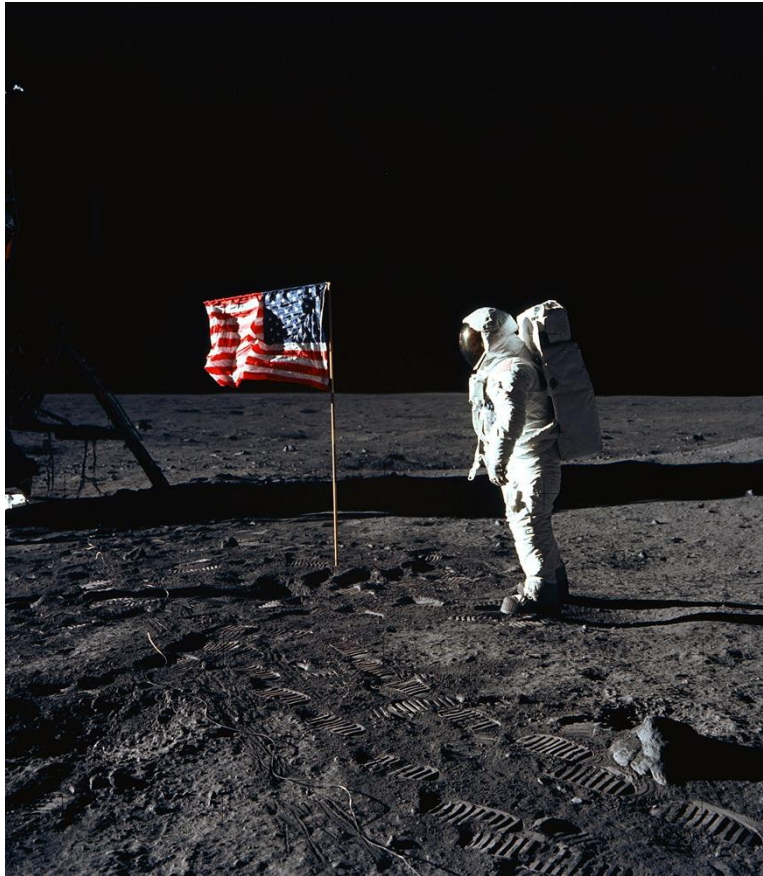
The Fascination with Space

Space has always fascinated humanity, inspiring myths, stories, and scientific curiosity.

The vastness and mystery of the universe drive our desire to explore and understand it.

What we always wondered:

- *“What is out there?”*
- *“Are we alone?”*
- *“How did the universe begin?”*



Introduction to Satellites

What is a Satellite?

A satellite is an artificial object placed in orbit around a celestial body, such as the Earth.

Types of Satellites:

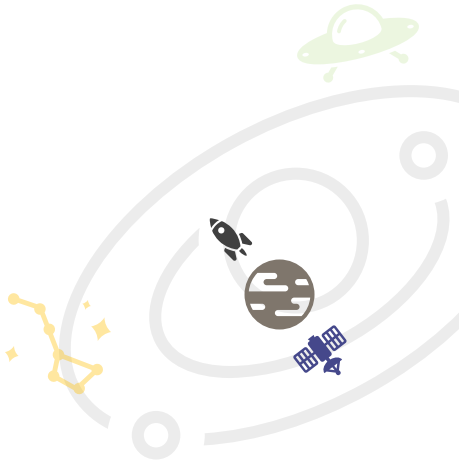
- Communication Satellites
- Weather Satellites
- Navigation Satellites (Galileo, GPS, GLONASS, BeiDou)
- Scientific Research Satellites

They provide essential data for various applications, improving our daily lives and advancing our understanding of the universe.

Space Environement

Key Characteristics of Space Environment

- **Vacuum:** Absence of atmosphere
- **Extreme Temperatures:** Fluctuations from intense heat to extreme cold
- **Radiation:** High levels of cosmic and solar radiation
- **Microgravity:** Near-weightless conditions.



In simple words, the space conditions are ***HARSH***.

Importance of Thermal Control

Why is Thermal Regulation Needed?

Thermal regulation is essential for the safe and efficient operation of spacecrafts in the harsh environment of space.

Spacecrafts are exposed to **extreme** thermal environments:

- Side of spacecraft facing Sun gets *very hot*
- Side of spacecraft facing away from set gets *very cold*

Electronic and mechanical equipment function best and are most dependable when kept within a specific temperature range, so we need a system to keep thermal stability.

Spacecraft Thermal Control System

The Spacecraft Thermal Control System (STCS) is a system which aims to simulate thermal environments and provide an interface for a controller to maintain the thermal stability of a spacecraft.

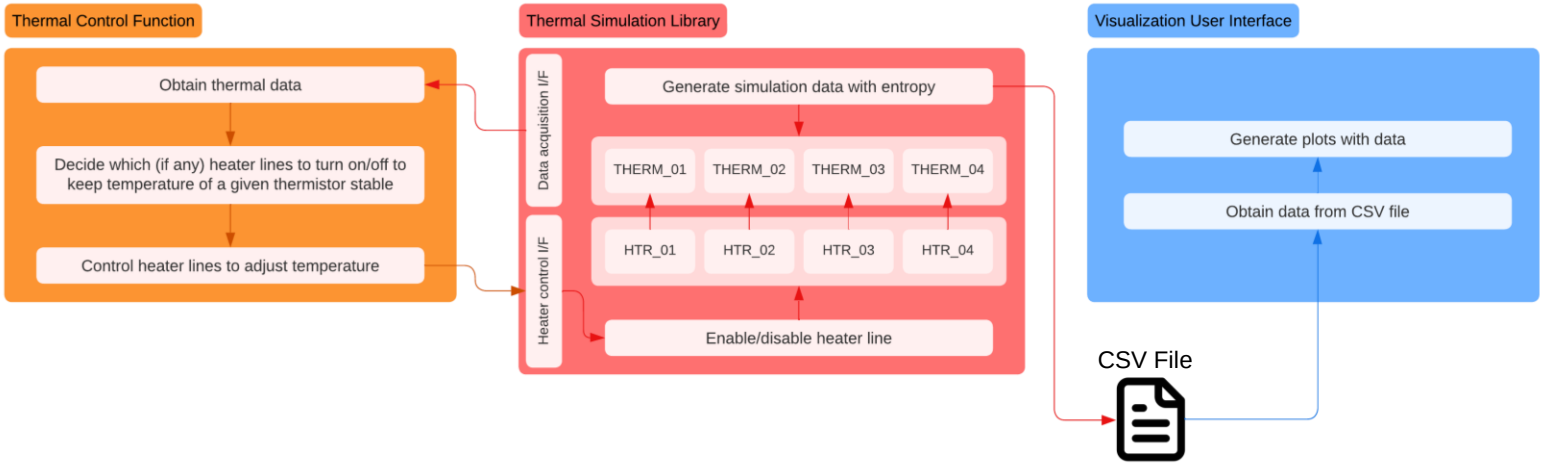
What is the system composed of?

- Simulator of a spacecraft thermal system
- Thermal control module to regulate the spacecraft thermals on the simulator
- Interface to visualize the spacecraft thermal values in real-time

Spacecraft Thermal Control System

The architecture of the STCS system is composed by three modules:

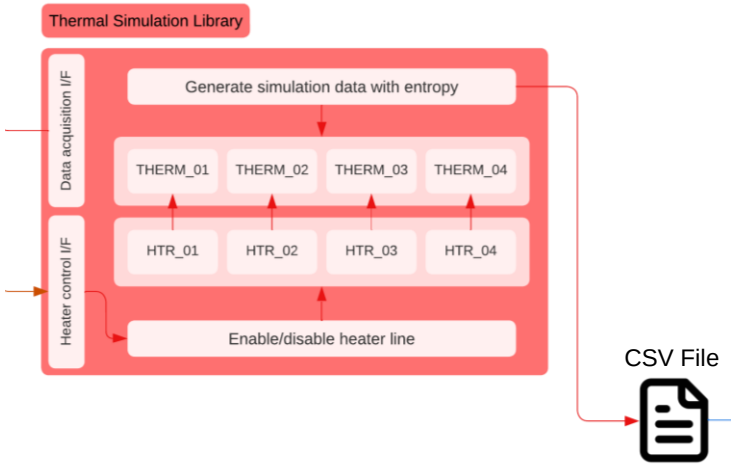
- Thermal Simulation Library (TSL): responsible for simulating the spacecraft thermal environment
- Thermal Control Function (TCF): capable of controlling and stabilizing the spacecraft thermal system
- Visualization User Interface (VUI): in charge of presenting the data about the spacecraft thermal system



Spacecraft Thermal Control System

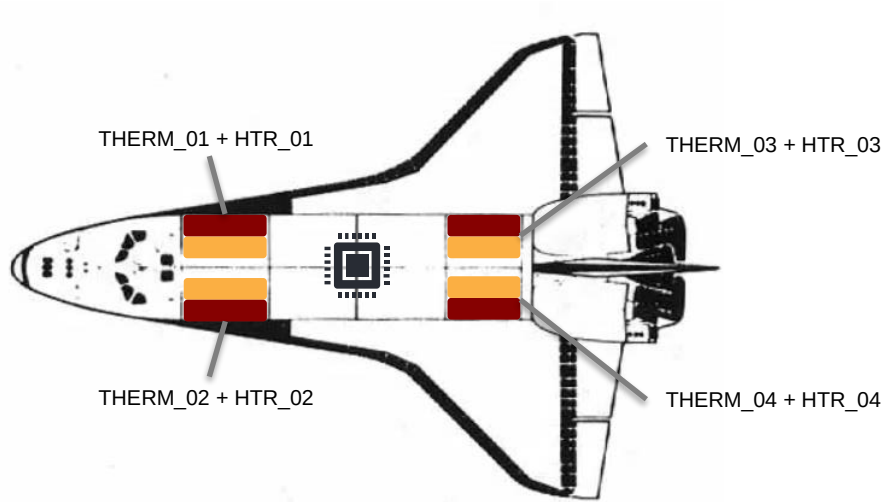
Thermal Simulation Library (TSL)

- Maintains 4 thermistors and 4 heaters, one heater linked to each thermistor
- Generates simulation data by updating the values of each thermistor based on entropy (eclipse periods, sun-exposure, ...)
- Provides an interface to obtain temperature from a given thermistor
- Provides an interface to enable/disable heaters
- Writes simulation data to a file



Spacecraft Thermal Control System

Electrical Architecture



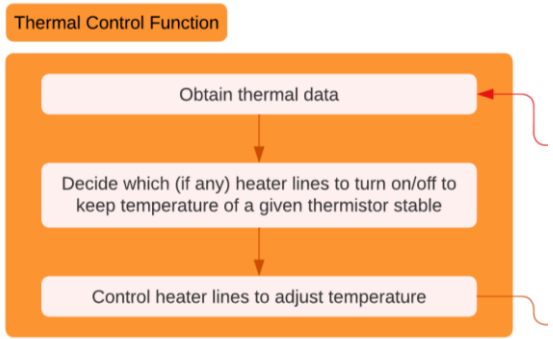
Legend:

- Thermistor
- Heater
- CPU

Spacecraft Thermal Control System

Thermal Control Function (TCF)

- Obtain thermal data from the interface provided by TSL
- Feed the thermal data to a Proportional-Integral-Derivate (PID) controller for each thermistor
- Power-on/off one or more heaters to adjust the temperature of each thermistor if needed



This module will be the focus of the activity.

INPUT: Software Requirements Specification (SRS) document

OUTPUT: Implementation of the Thermal Control Function module

Spacecraft Thermal Control System

Thermal Control Function (TCF)

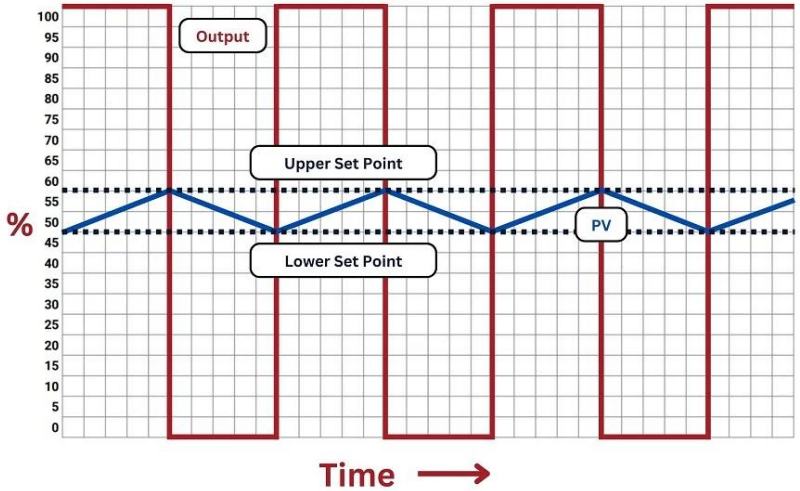
Bang-bang controller

- Simple on/off control mechanism
- Switches between two extreme states (e.g., fully on or fully off)

EXAMPLE

Thermostat controlling a heater:

- Heater turns **on** when temperature **drops below** a threshold
- Heater turns **off** when temperature **exceeds** a threshold



Advantages	Disadvantages
Easy to implement	Causes oscillations around setpoint
Quick response time	Not suitable for precise control

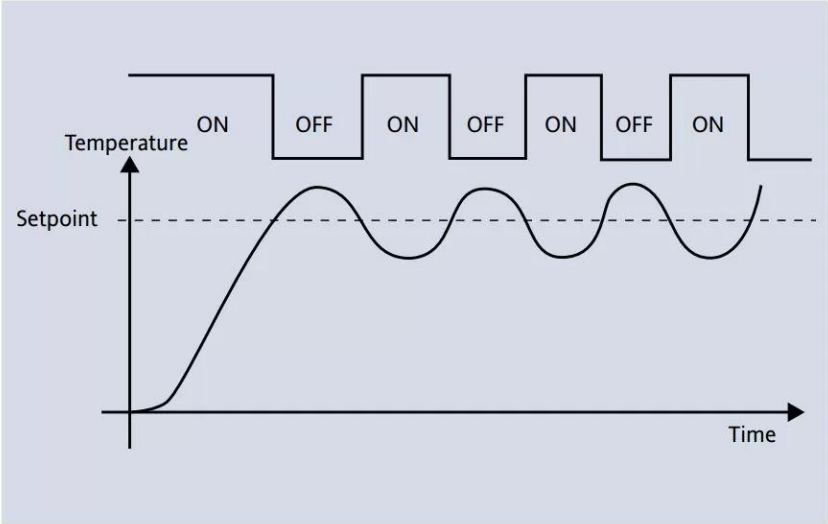
Spacecraft Thermal Control System

Thermal Control Function (TCF)

Proportional-integral-derivative controller (PID)

- Advanced control mechanism providing smooth and precise control
- Combines three components:
  - **Proportional (P):** output proportional to current error
  - **Integral (I):** output based on accumulated past errors
  - **Derivative (D):** output based on rate of change of error

Control Output = P + I + D

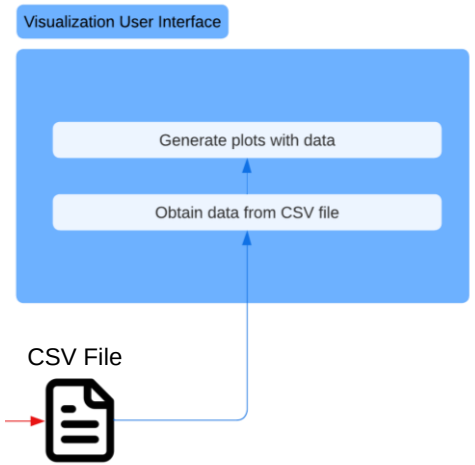


Advantages	Disadvantages
Provides precise/stable control	More complex to implement and tune
Damps system oscillations	Tuning params can be challenging

Spacecraft Thermal Control System

Visualization User Interface (VUI)

- Reads data from the CSV file
- Generates plots and display data (e.g., thermistor temperature, heater power status, entropy activations, ...)



Tools and Technologies

- **Thermal Control Function**: implemented in C using standard libraries or in alternative in Python.
- Communication between the controller and the simulator is done through 2 unidirectional pipes:
  - **INFO_PIPE:** TSL writes the temperatures of the simulation to the pipe.
  - **RESPONSE_PIPE:** TCF writes to the pipe specifying which heaters to turn on.
- Message structures used by the TCF and TSL:
  - **TSL write to INFO_PIPE:**
    {THERM-01_TEMP}-{HTR-01_PWR};{THERM-02_TEMP}-{HTR-02_PWR};...
  - **TCF write to from RESPONSE_PIPE:**
    {HTR-01_PWR};{HTR-02_PWR};...

⚠ The project must be runnable on an Ubuntu environment.
For Windows users you might use WSL.

Conclusion

- **Objective:** implementation of the Thermal Control Function (TCF) module capable of controlling a spacecraft thermal system simulation.
- Feel free to ask questions.
- The objective is to have a good final product but don’t forget to enjoy the process, take the opportunity to learn and most of all: **have fun**!