GSAW 2008

# USE OF PYTHON AS A SATELLITE OPERATIONS AND TESTING AUTOMATION LANGUAGE

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INNOVATING SOLUTIONS

# INTRODUCTION

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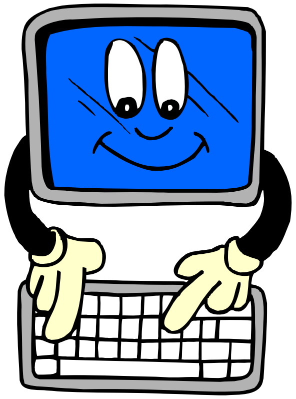
# INTRODUCTION

- Presentation shares the results of GMV's experience regarding:
  - – **Next generation automation layer** for Satellite Command and Control (SCC)
    - Required to interact with the core of the SCC via an existing **Application Programming Interface** (API), exporting its services as functions available from a dynamic language.
    - Layer was expected to support
      - – Automation of **operational** satellite control procedures
      - – Automation of **non-regression SCC testing** during development, integration and maintenance.
      - – All previous points also applied to **ground equipment**



Broad view of automation, applied well beyond actual operational procedures

– In particular, this presentation summarizes our analysis regarding the feasibility of the use of **Python** as the scripting language

# SCC AUTOMATION LANGUAGES

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# EXISTING LANGUAGES FOR SCC AUTOMATION

- SCC automation approaches:
  - **procedural scripts**
    - Space-specific languages
    - General purpose languages
  - rule-based expert systems
  - finite state models

our focus

- Multiple **space-specific languages currently used**:
  - **STOL**: Satellite Test and Operations Language
    - Originally developed by NASA, multiple flavors
    - Widely used by many GOTS and COTS
  - **PLUTO**: some ESA missions (SCOS-2000)
  - Multiple **proprietary languages** used by different companies: SOL (GMV), CCL (Harris), OCIL / CECIL (Raytheon), PIL (Astrium), SCL (ICS), etc

- **General purpose languages** used in some missions: Perl, Tcl

# CUSTOM vs GENERAL PURPOSE LANGUAGES

| | SPACE-SPECIFIC (eg. STOL) | GENERAL PURPOSE (eg. Python) |
|---|---|---|
| PROS | □ (Sometimes) more user friendly for non-programmers<br>□ Adapted to satellite operations<br>□ High reliability | □ Open source<br>□ Very powerful<br>□ Portable<br>□ Language can be easily restricted / extended<br>□ Wide availability of tools and programmers |
| CONS | □ Proprietary language and/or tools<br>□ Portability issues<br>□ Limited, enhancements are expensive | □ Potentially less readable if coding is not done carefully<br>□ Too powerful? |

# HOW ABOUT PYTHON?

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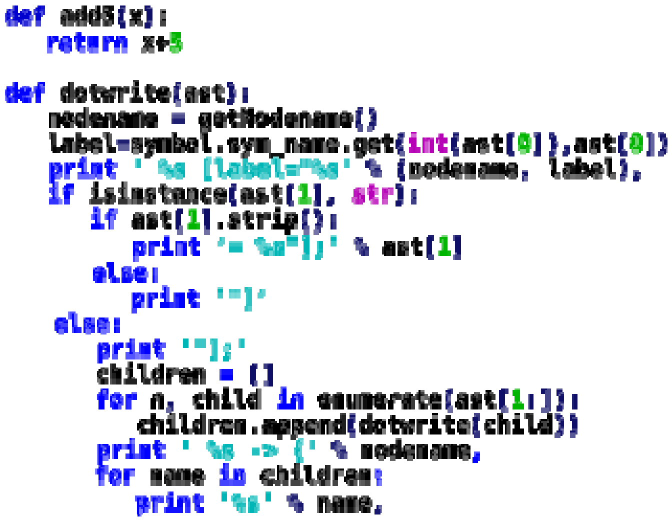
# Python

- Python is a **portable, open, high-level, object-oriented, dynamic language**
- Conceived in the 80s, **used massively since the 90s**
- Recognized widely for its **readability**, **maintainability** and **modifiability**, key aspects for complex procedures that may be modified multiple times throughout a mission.
- **Performance** is much better than most other dynamic languages.
  – Compiled to bytecode
- **Widely supported by the software community**, which guarantees the availability of good programmers, Integrated Development Environments (IDEs) and extensions.



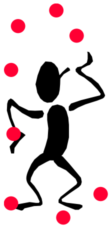
```
def add5(x):
    return x+5

def dotwrite(ast):
    nodename = getNodename()
    label=symbol.sym_name.get(int(ast[0]),ast[0])
    print ' %s [label="%s' % (nodename, label),
    if isinstance(ast[1], str):
        if ast[1].strip():
            print '= %s"];' % ast[1]
        else:
            print '"]'
    else:
        print '"];'
        children = []
        for n, child in enumerate(ast[1:]):
            children.append(dotwrite(child))
        print ' %s -> {' % nodename,
        for name in children:
            print '%s' % name,
```

Multiple successful applications in space business
E.g. Shuttle Mission Design

# ADVANTAGES OF THE USE OF PYTHON (1)

- **Portable**
  - Windows (XP, CE, Pocket PC), Linux, UNIX, Macintosh
  - Many others: AIX, AROS, AS/400, iPOD, OS/2, Palm OS, Playstation, Psion, VxWorks, Nokia cell phones, .NET, Java Virtual Machine, ...

- **Open**
  - Free, even for commercial use.
  - Interpreter can be embedded in products (no license fee)
  - Open source, no GPL-like traps

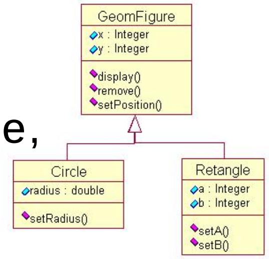


- **Dynamic**
  - Dynamically typed and interpreted, ideal for fast scripting

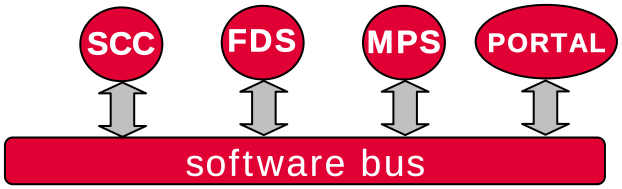
- **Powerful**
  - Complex built-in data structures (e.g. flexible arrays, lists, dictionaries)
  - Great variety of program control instructions
  - **Productivity 5 – 10 times higher than Java**
  - Supports exception handling
  - Automatic memory management and garbage collection
  - Language is extensible

# ADVANTAGES OF THE USE OF PYTHON (2)

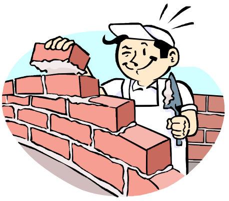
- **Object orientation**, with all the associated benefits (reuse, abstraction, scalability, …)
  - Supports classes, inheritance, templates



- Easy integration with
  - existing Service Oriented Architecture (**SOA**) implementations
  - **Web Services** (WSDL)
  - **GMSEC** API (Python supported)



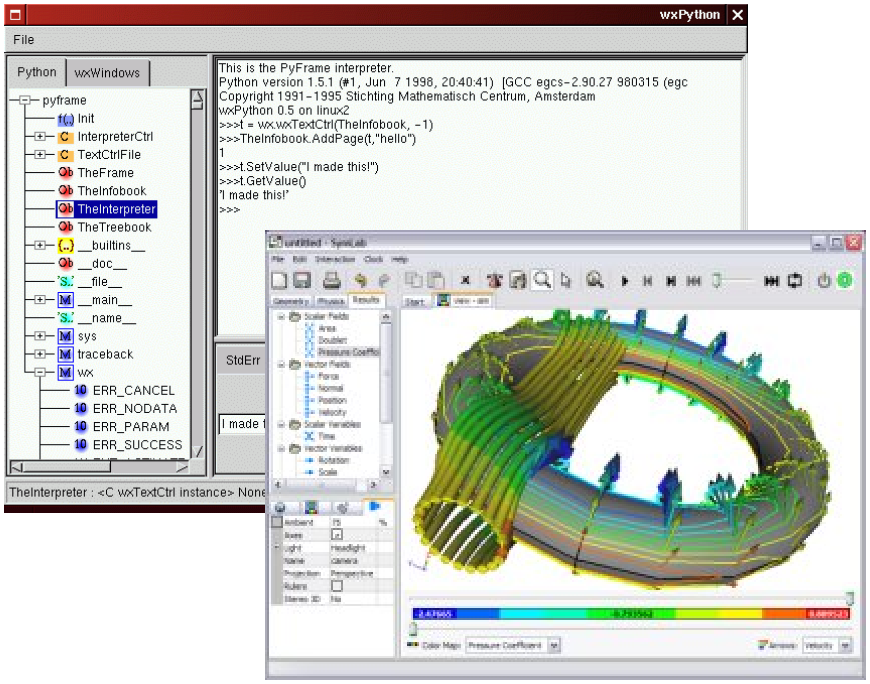
- **Built-in development capabilities**, given as language modules
  - Automatic documentation generation
  - Unit testing, regression testing
  - Debugger, profilers, interpreter, compiler



- Availability of **multiple modules** for
  - **XML** processing: Multiple applications: XTCE DB parsing, SOAP messaging, etc
  - **Communications**: Sockets, Internet access, RPC, email
  - Time **performance measurement**
  - **Many others**: database access, math, data compression, multi-threading, cryptography, operating system access, etc

# ADVANTAGES OF THE USE OF PYTHON (3)

- Availability of bindings for multiple **GUI-development toolkits** (Qt4, GTK2, Tk, wxWidgets, etc)



```
This is the PyFrame interpreter.
Python version 1.5.1 (#1, Jun  7 1998, 20:40:41)  [GCC egcs-2.90.27 980315 (egc
Copyright 1991-1995 Stichting Mathematisch Centrum, Amsterdam
wxPython 0.5 on linux2
>>>t = wx.wxTextCtrl(TheInfobook, -1)
>>>TheInfobook.AddPage(t,"hello")
1
>>>t.SetValue("I made this!")
>>>t.GetValue()
'I made this!'
>>>
```

TheInterpreter : <C wxTextCtrl instance> None

- Wide variety of **plug-ins for Eclipse** (a popular open development platform) can be used to work with Python.

- Availability of multiple, powerful, **free tools** for
  - Development
  - Source code inspection and metrics generation
  - Debugging, testing
  - Configuration management

- Wide support by **commercial tool vendors**

# RISKS OF THE USE OF PYTHON

- Language may be ***too powerful*** and complex for non-programmers.
  - This can be handled by restricting the use of certain instructions from the development environment
- **Readability** may be worse than space-specific languages if coding is not done carefully
  - Strict coding standards are needed
  - Coding can be abstracted for non-programmers using a visual environment
- **Evolution of language** is controlled by others
  - This is part of the deal of using a general-purpose language
  - Compensated by all the advantages
  - A mission can just freeze the Python version & development environment and use updates on a case-by-case basis
- **Dependency** on third-party software (the interpreter)
  - But it is open source

# INTEGRATION OF PYTHON WITH AN SCC

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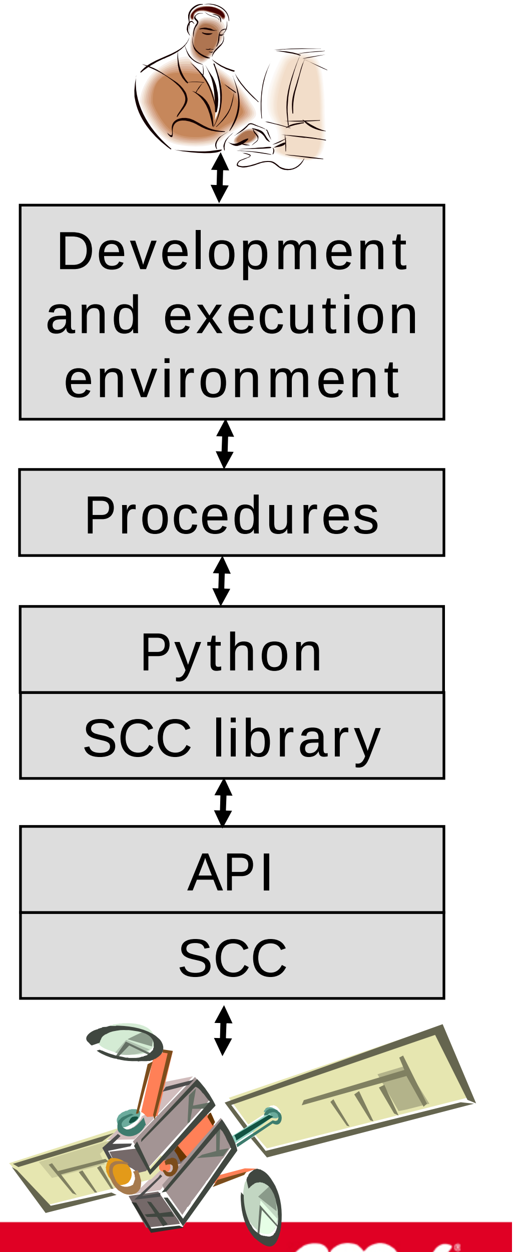
# INTEGRATION OF PYTHON WITH AN SCC

- A **tool** was created to develop, test, modify and schedule the Python procedures.
  - Target users: Satellite operators
  - Environment fully customized to take into account the target automation requirements
    - Operational procedures
    - SCC non-regression testing
    - Ground equipment operations & testing

- Access to the SCC API is enabled by a **Python library that encapsulates all the standard API services**



Development and execution environment

Procedures

Python

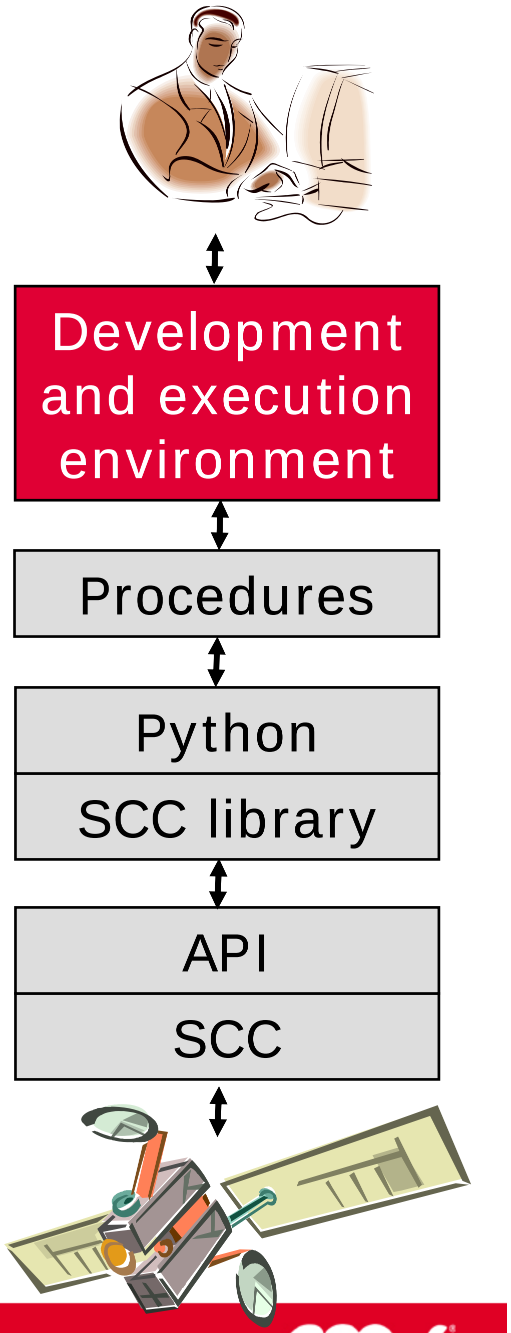
SCC library

API

SCC

# DEVELOPMENT AND EXECUTION ENVIRONMENT (1)

- **Development** environment
  - **Objective**: Deliver the most powerful support for procedure development and validation
  - Based on **Eclipse / RCP** (Rich Client Platform):
    - Open Development Platform
    - Widely adopted as Integrated Development Environment
    - Open source
    - Supports scripting languages
    - RCP: specifically designed to build custom IDEs
  - **Capabilities**
    - Repository
    - Edition: Including syntax highlighting
    - Verification: Including procedure verification against the satellite database
    - Automatic look-up of class methods, function arguments, etc
    - Metric generation, coverage statistics
    - Debugging



Development and execution environment

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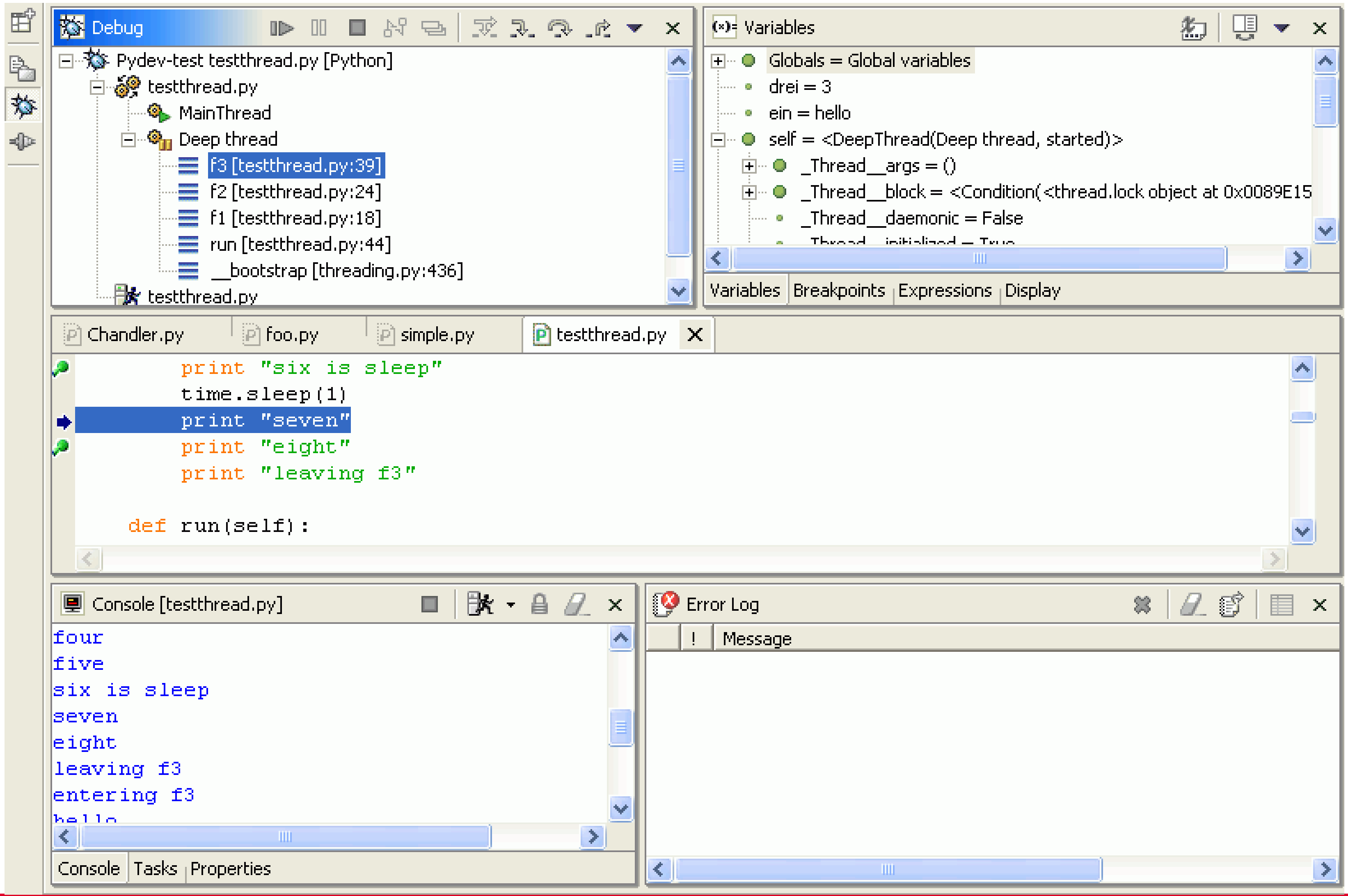
# DEVELOPMENT AND EXECUTION ENVIRONMENT (2)



```
Pydev-test testthread.py [Python]
  testthread.py
    MainThread
    Deep thread
      f3 [testthread.py:39]
      f2 [testthread.py:24]
      f1 [testthread.py:18]
      run [testthread.py:44]
      __bootstrap [threading.py:436]
  testthread.py
```

```
Globals = Global variables
drei = 3
ein = hello
self = <DeepThread(Deep thread, started)>
  _Thread__args = ()
  _Thread__block = <Condition(<thread.lock object at 0x0089E15
  _Thread__daemonic = False
```

```
        print "six is sleep"
        time.sleep(1)
        print "seven"
        print "eight"
        print "leaving f3"

    def run(self):
```

```
four
five
six is sleep
seven
eight
leaving f3
entering f3
hello
```

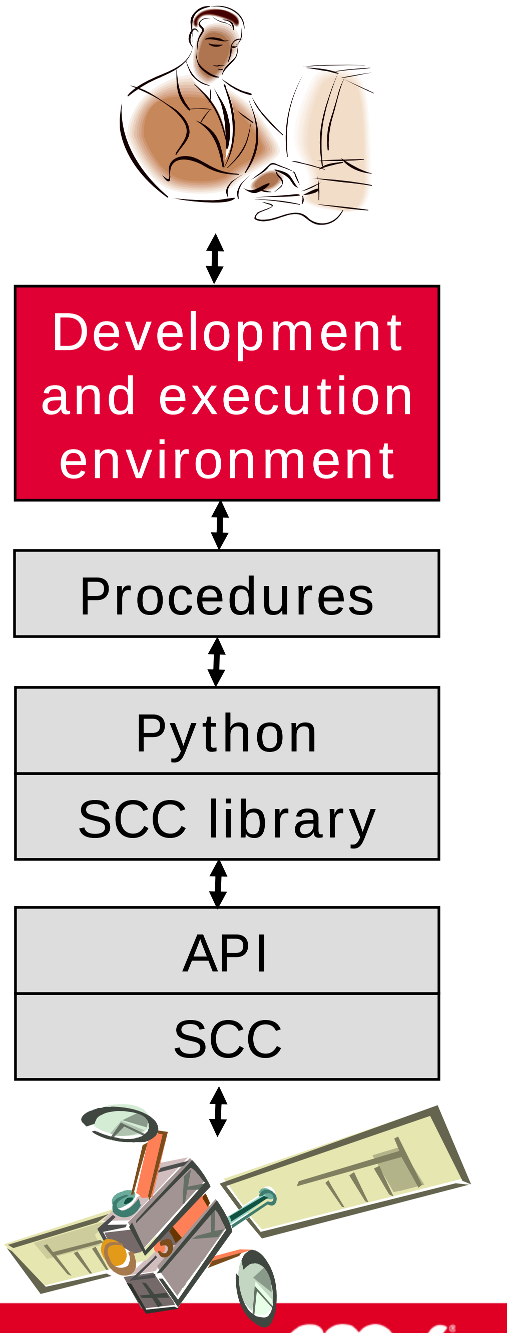
| ! | Message |
|---|---|

# DEVELOPMENT AND EXECUTION ENVIRONMENT (3)

- **Procedure execution** services
  - – Procedure execution (cold/warm start, start at, etc)
    - Parallel execution supported
  - – Procedure control (pause, resume, step, etc)
    - Supports step-by-step execution as well as spacecraft protocol details (eg. TC verification)
  - – Procedure monitoring (execution status, etc)

- **Repository browser**
  - – browse (read only) validated procedures

- **Scheduler**
  - – Schedule, control and monitor procedures
    - Triggers, events, pause, resume, etc



Development and execution environment

Procedures

Python

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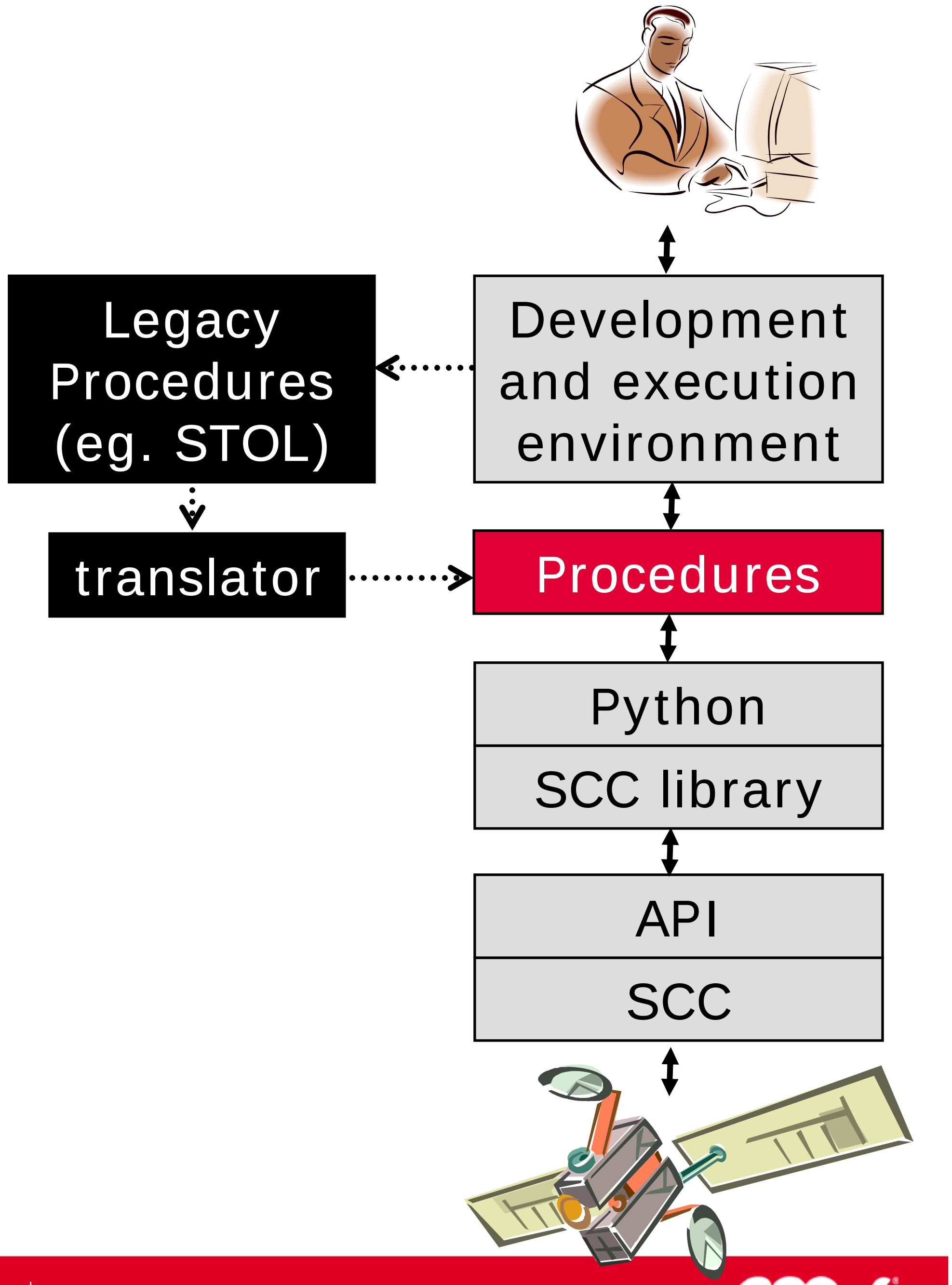
SCC

# PROCEDURES (1)

- Nominally, **native procedures** written in Python
- Support for existing space-specific languages provided by the development of **conversion tools** that generate the extended Python scripts from the legacy operational procedures.
  - STOL, CECIL
  - Procedures in XML
- This is very important to **minimize cost and risk** when
  - adapting standard platform-specific procedures from certain manufacturers
  - replacing an operational SCC that used procedures in these languages



Legacy Procedures (eg. STOL)

Development and execution environment

translator

Procedures

Python

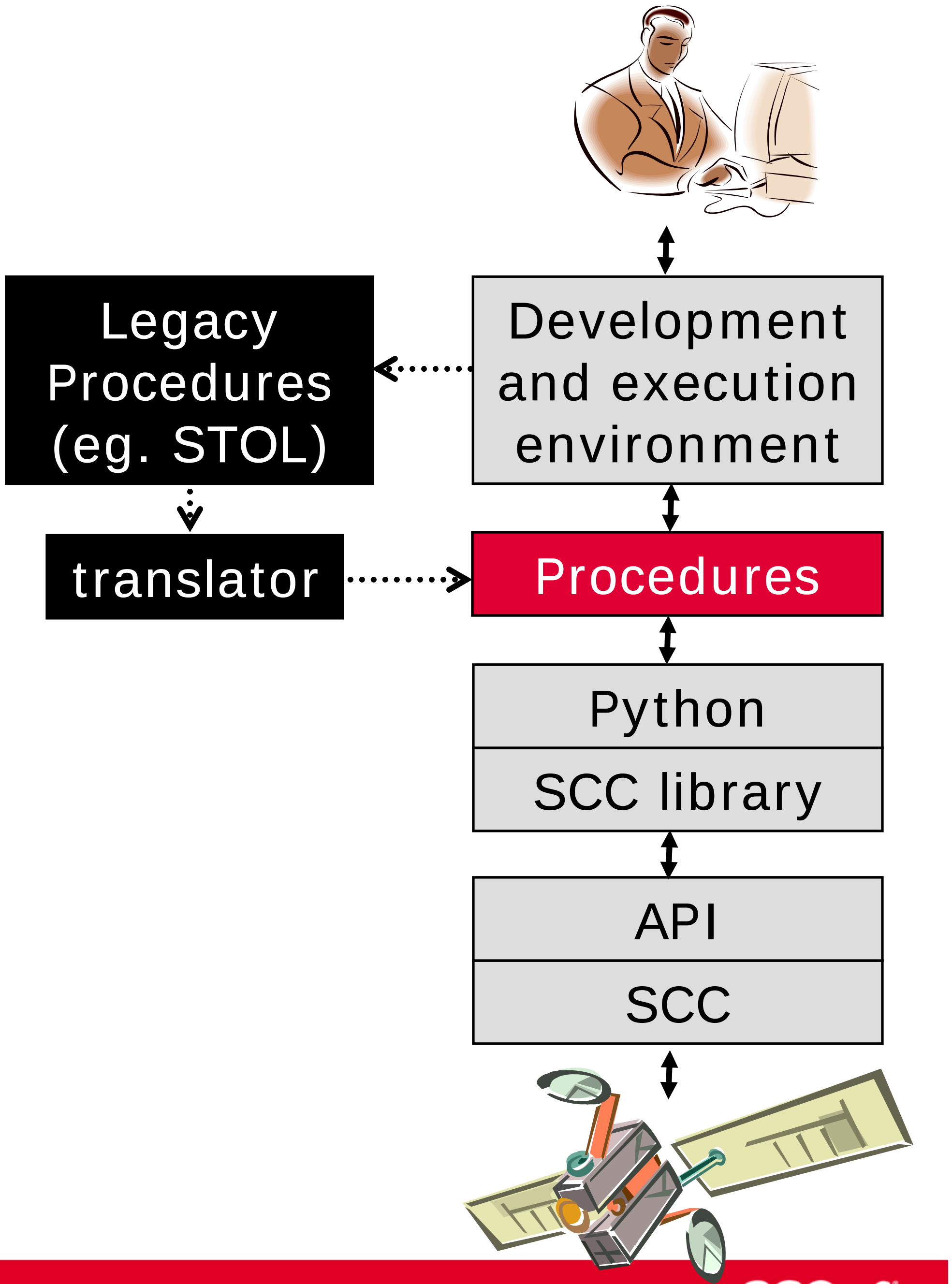
SCC library

API

SCC

# PROCEDURES (2)

- The flexibility of Python has made it possible to perform this **conversion in two ways**:
  - As a **batch process**, where a set of scripts have been converted to the extended Python
  - As a **real-time conversion**, allowing the operator to keep using the original language for step-by-step execution monitoring and for the implementation of modifications
- Maintains **traceability** between lines of code of original procedures and translated procedures



Legacy Procedures (eg. STOL)

translator

Development and execution environment

Procedures

Python

SCC library

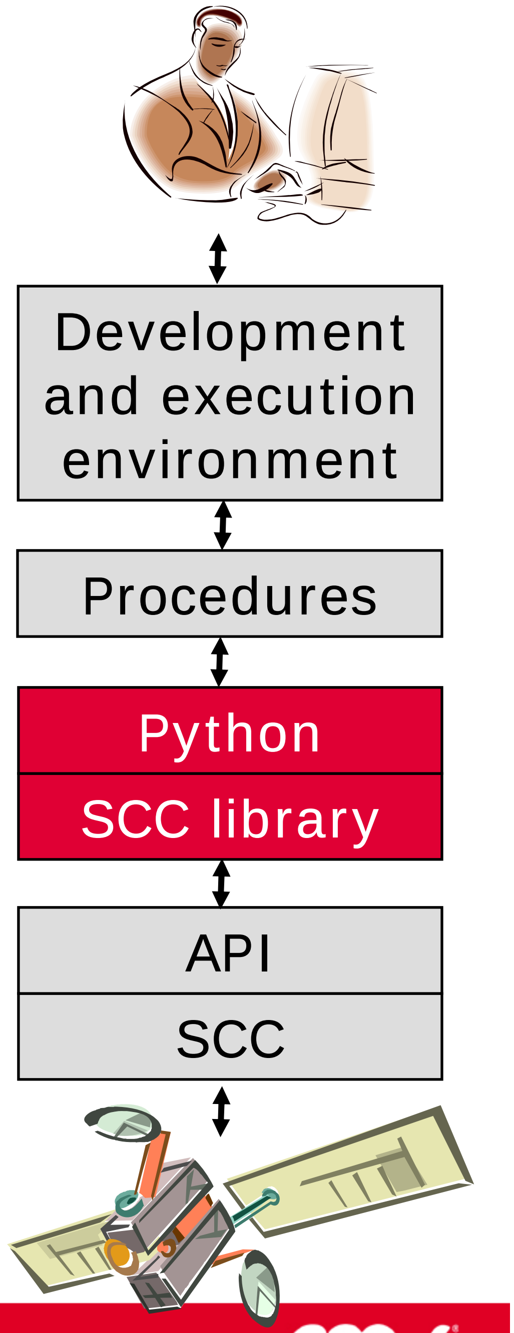
API

SCC

# Python + SCC LIBRARY

- **Python**: Includes
  - – Interpreter
  - – Multiple extensions supporting arrays, vectors, XML, GUIs, HTML, etc

- **SCC Library**
  - – Provides access to **API services** from the Python code
  - – Services are **encapsulated** in a class, services become class methods
  - – Potentially **this class could be standardized** to allow the operator to:
    - Use the same procedures with different SCCs (e.g. heterogeneous fleet using different products)
    - Migration from a legacy SCC to a new product



Development and execution environment

Procedures

Python

SCC library

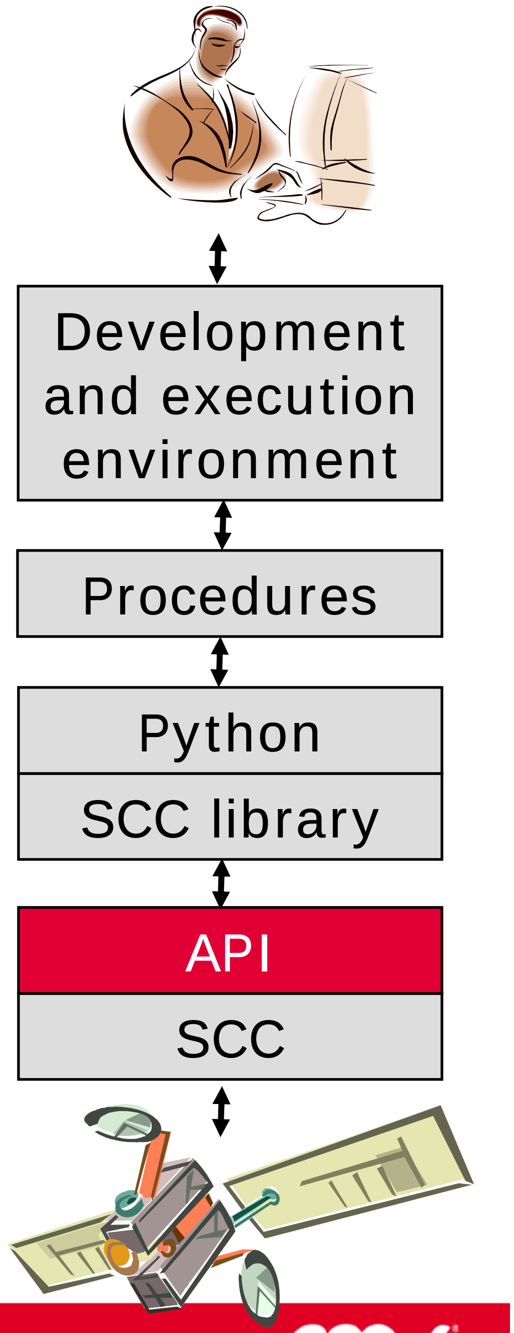
API

SCC

# SCC API

## API Services

- Access to satellite **database** definitions
- **Telemetry** (TM)
  - TM access (real-time, retrieval, packets and parameters, single parameter, parameter sets)
  - TM injection
- **Telecommands** (TC)
  - TC injection (real-time, retrieval, filtering criteria)
  - TC history access
  - TC status monitoring
- **Event and out-of-limits** access (real-time, retrieval, filtering criteria)
- **Event injection**
- **Modification of out-of-limit definitions**
- **Open** predefined TM **displays**



Development and execution environment

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# LESSONS LEARNED

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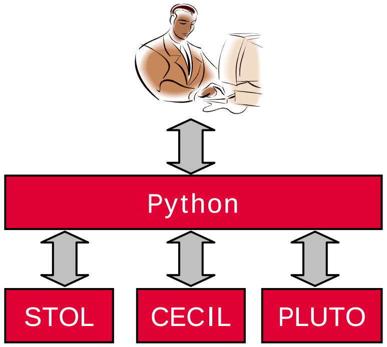
# LESSONS LEARNED (1)

- Many **space-specific languages** currently used for the development of operational procedures were **defined decades ago** and are **not used outside of the space industry**. In many cases they are **proprietary** and require **expensive** products.

- Future **support for proprietary languages and** availability of **tools** is not guaranteed. Some operators have had serious problems replacing a system once the HW became obsolete, typical in a GEO mission (> 15 years)
- Lessons from **Ada**:
  - Language designed under contract to the US DoD during 1977 – 1983
  - Targeted at embedded and real-time systems
  - Mandatory for new software DoD projects since 1987
  - Excellent language, used successfully for thousands of projects
  - 2003, Software Engineering Institute:

    ***"Due to a dearth of tools and compilers and lack of trained, experienced programmers [...] Ada is a programming language with a dubious or nonexistent future"***

# LESSONS LEARNED (2)



Python

STOL CECIL PLUTO

- Operators with a **heterogeneous fleet** usually end up having to use different languages. This increases training & operations costs and increases the complexity of the system.
- Python allows the definition of a **homogeneous front-end** for a heterogeneous fleet

- **Coding rules, customized development environment and training** needed to guarantee the high quality & maintainability of procedures
- With Python, operators can **benefit** enormously from the **software community**:
  - Using **modern, powerful, open source languages** like Python and **tools** like Eclipse/RCP widely supported
  - Approach allows the operators to have an **open, integrated environment** for operational and testing procedure development, verification, execution, configuration management and metric generation
  - It also **reduces** the **dependency** on proprietary technologies and the **risks** of software obsolescence

# Thank you

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