# Software Engineering Practices for Space Experiments

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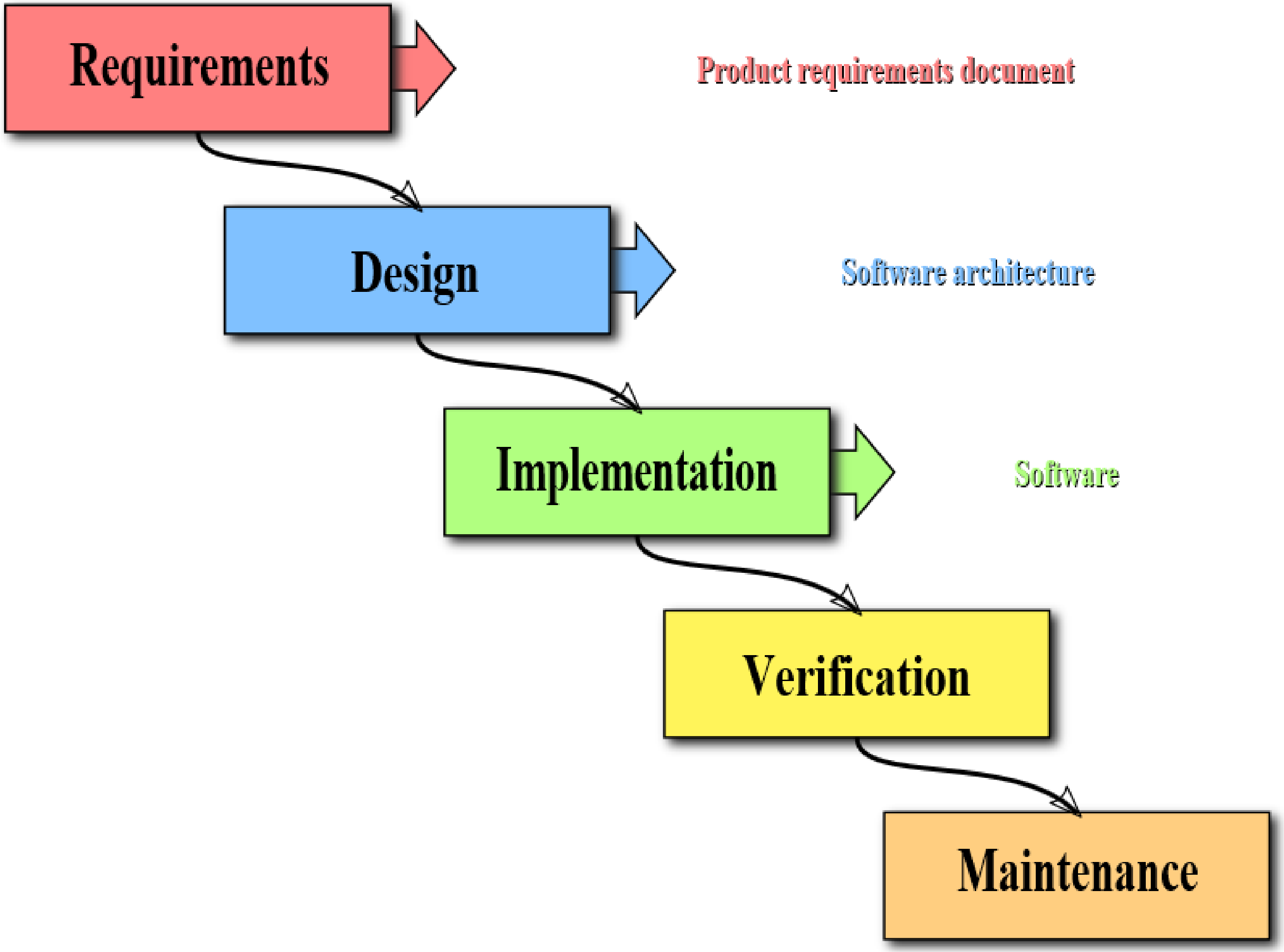
# Introduction

- Funding agencies call for reliable software development and the application of established standards.
- University courses should train students to understand software engineering.
- Scenario 1: Software Development for a New Space Experiment
- Scenario 2: Updating of an Existing System
- Scenario 3: Outlook

## Scenario 1:
## Software Development for a New Space Experiment

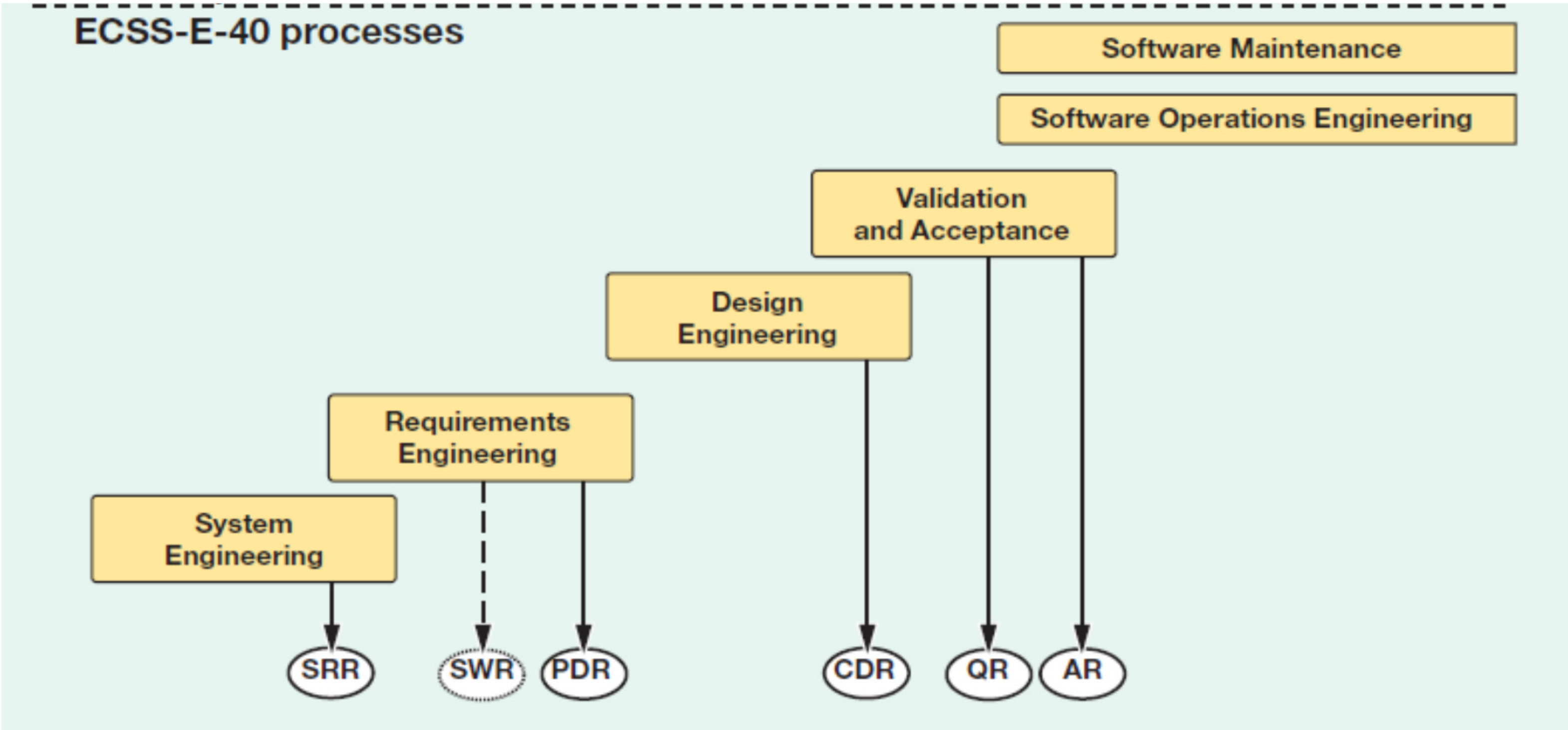
- Coding starts after compilation of requirements and software architecture design.
- University graduates should be prepared to follow this approach.

https://commons.wikimedia.org/wiki/File:Waterfall_model.svg



http://www.esa.int/esapub/bulletin/bullet111/chapter21_bul111.pdf

**Introducing ECSS Software-Engineering Standards within ESA**
– Practical approaches for space- and ground-segment software



## Scenario 1:
## Funding Agencies Require Documents

- A specific document is an Algorithm Theoretical Basis Document (ATBD)
- This document shall be written before software coding starts.

**Soil Moisture Active Passive (SMAP)**

**Algorithm Theoretical Basis Document**
**SMAP Level 4 Carbon Data Product (L4_C)**

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https://smap-archive.jpl.nasa.gov/science/dataproducts/ATBD/

## Algorithm Theoretical Basis Documents (ATBDs)

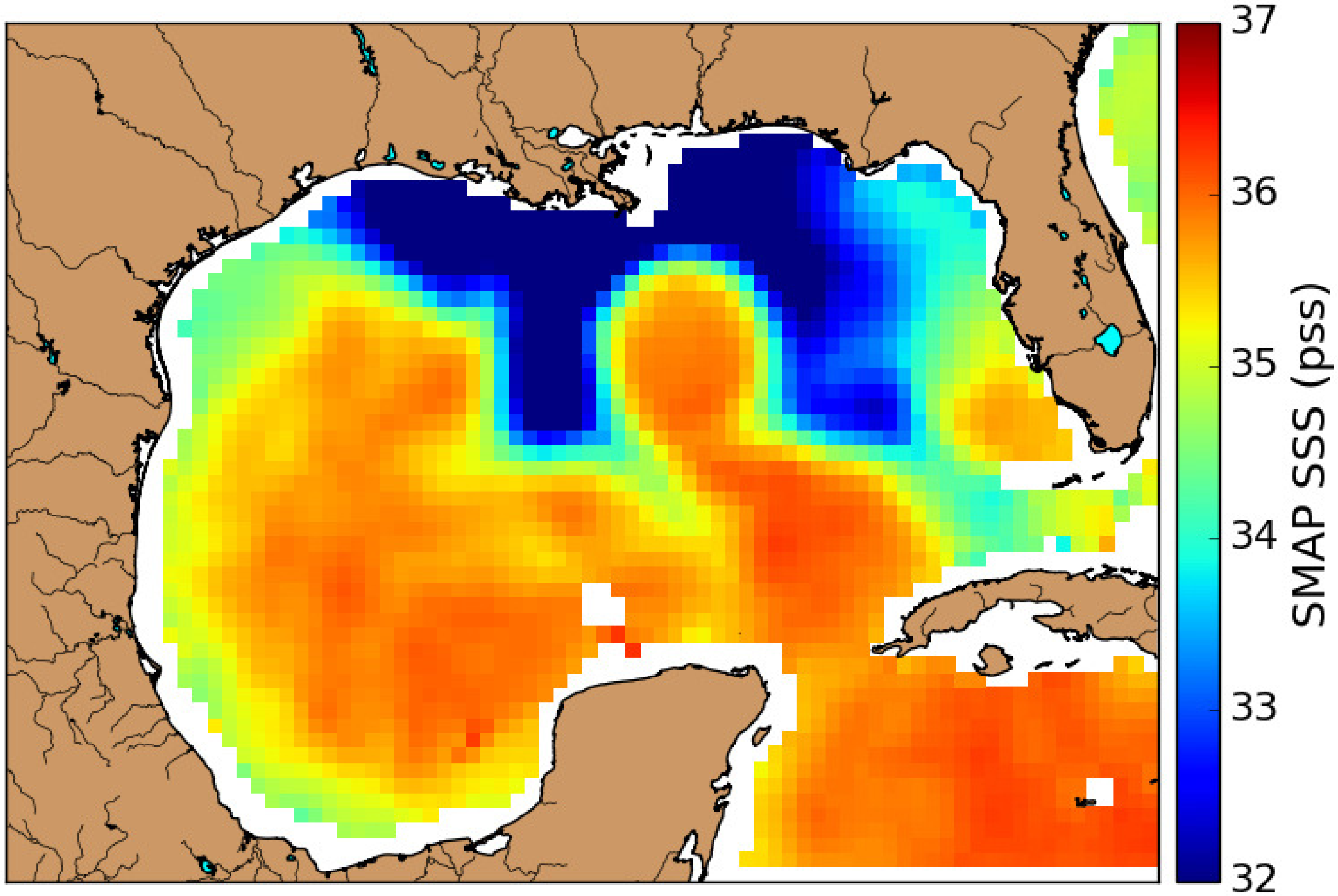
Algorithm Theoretical Basis Documents (ATBDs) provide the physical and mathematical descriptions of the algorithms used in the generation of science data products. The ATBDs include a description of variance and uncertainty estimates and considerations of calibration and validation, exception control and diagnostics. Internal and external data flows are also described.
ATBDs are written for all SMAP science data products from Level 1B through Level 4.
The SMAP ATBDs were peer-reviewed by panels in 2011 and 2013 and are currently at Revision A. The ATBDs may undergo additional updates at data releases after SMAP launch.

- L1B&C_S0: Level 1B and Level 1C Radar Data Products (PDF, 2.68 MB)
- L1B_TB: Level 1B Radiometer Data Product (Rev A) (PDF, 6.17 MB)
- L1C_TB: Level 1C Radiometer Data Product (PDF, 2.95 MB)
- L2&3_SM_P: Level 2 and Level 3 Radiometer Soil Moisture Data Products (Rev A) (PDF, 4.3 MB)
- L2&3_SM_A: Level 2 and Level 3 Radar Soil Moisture Data Products (Rev A) (PDF, 4.07 MB)
- L2&3_SM_AP: Level 2 and Level 3 Radar/Radiometer Soil Moisture Data Products (Rev A) (PDF, 5.65 MB)
- L3_FT_A: Level 3 Freeze/Thaw Data Product (Rev A) (PDF, 2.66 MB)
- L4_SM: Level 4 Surface and Root Zone Soil Moisture Data Product (Rev A) (PDF, 4.59 MB)
- L4_C: Level 4 Carbon Data Product (Rev A) (PDF, 2.71 MB)

**Ancillary Data Reports** The SMAP Ancillary Data Reports provide descriptions of ancillary data sets used with science algorithm software in generating SMAP science data products. The Ancillary Data Reports may undergo additional updates as new ancillary data sets or processing methods become available.

- Crop Type (PDF, 1.58 MB)
- Landcover (PDF, 324 KB)
- Digital Elevation Model (PDF, 634 KB)
- Soil Attributes (PDF, 1.98 MB)
- Static Water Fraction (PDF, 828 KB)
- Urban Area (PDF, 2.13 MB)
- Vegetation Water Content (PDF, 1.74 MB)
- Permanent Ice (PDF, 366 KB)
- Precipitation (PDF, 694 KB)

# https://www.nasa.gov/smap



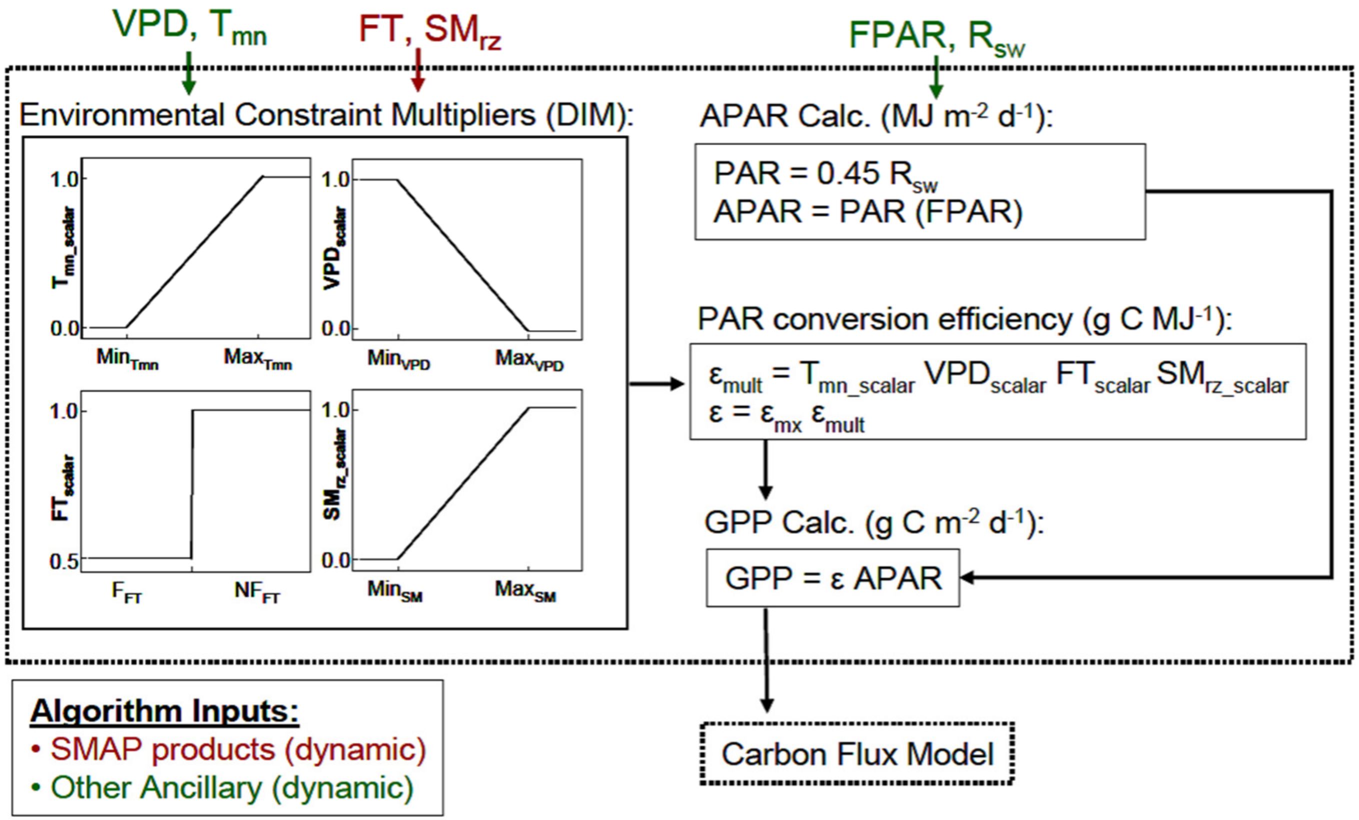
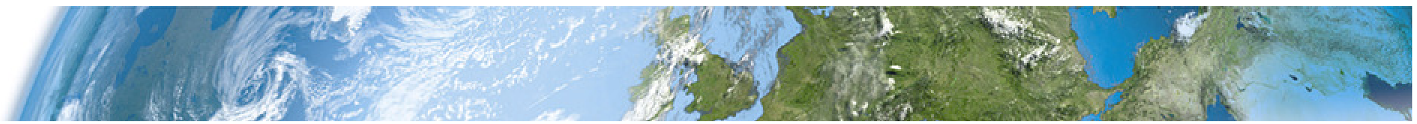



***Figure 4a**. Baseline L4_C LUE model structure for estimating GPP. Arrows denote the primary pathways of data flow, while boxes denote the major process calculations. Primary inputs include daily root zone soil moisture ($SM_{rz}$) and landscape freeze/thaw (FT) status from SMAP L4_SM and L3_SM_A products (in red), and other dynamic ancillary inputs (in green) including MODIS (MOD/MYD15) FPAR and reanalysis (GMAO) daily surface meteorology, including vapor pressure deficit (VPD), minimum air temperature ($T_{mn}$) and incident solar shortwave radiation ($R_{sw}$). Model calculations are performed at 1-km spatial resolution using dominant vegetation class and BPLUT response characteristics for each grid cell defined from a global land cover classification. The resulting GPP calculation is a primary input to the L4_C terrestrial carbon flux model below (**Fig 4b**).*

# MERIS ATBD 2.24

## Vicarious adjustment of the MERIS Ocean Colour Radiometry



# Text Excerpt from MERIS ATBD

- The targeted reflectance required in the gain computation would ideally be built from concomitant ground measurements of water reflectance, atmospheric aerosol reflectance and atmospheric total transmittance. While reliable *in situ* water reflectances are accessible, simultaneous measurements with aerosol properties are not widely available (Franz *et al.*, 2001). To remedy this lack of *in situ* measurements, published procedures have proposed to use the atmospheric variables determined algorithmically by the atmospheric correction above the marine target, after insuring a proper calibration of the NIR bands (Franz *et al.* 2007, Bailey *et al* 2008). This implies a two-step procedure:
- 1. First, the NIR bands used in the atmospheric correction, 779 and 865 nm, are independently adjusted, if necessary;
- 2. Then, the atmospheric correction is applied, yielding to path reflectance and transmittance in the VIS bands considered as sufficiently accurate to build the targeted TOA reflectance:

# Scenario 1: Lessons Learned

- There are good ATBDs and better ATBDs
- How can we train students to exploit ATBDs for software development?
- How can we train students to write an excellent ATBD?

# Scenario 2: Updating of an Existing System

- Problem description: Selected components of an existing operational system shall be updated
- Goal: more accurate physics, shorter run-times, etc.
- Updated components have to follow coding conventions and best practices during testing and installation

# https://msdn.microsoft.com/en-us/library/ff926074.aspx
## C# Coding Conventions (C# Programming Guide)

- **Commenting Conventions**

- Place the comment on a separate line, not at the end of a line of code.
- Begin comment text with an uppercase letter.
- End comment text with a period.
- Insert one space between the comment delimiter (//) and the comment text, as shown in the following example.
- C#

```
// The following declaration creates a query. It does not run
// the query.
```

- Do not create formatted blocks of asterisks around comments.

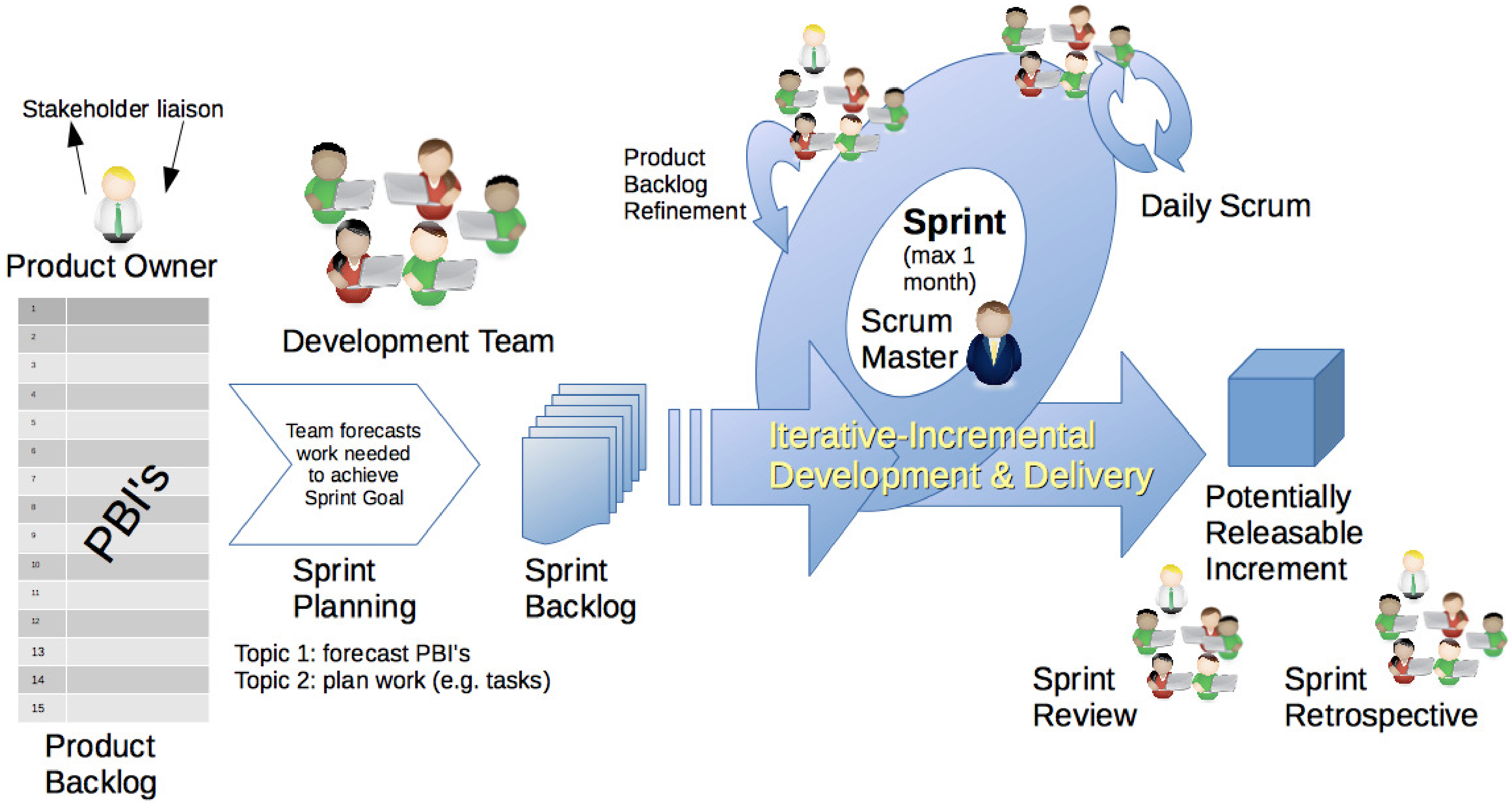
# Scenario 2: Lessons Learned

- The adherence to coding conventions may demotivate software developers.
- Any new code has to be carefully tested, validated and inserted.
- Testing strategies can be understood quickly.
- However, how can a student learn to validate new code (e.g., validation of higher physical accuracy?)

# Scenario 3: Outlook

- Today, software developers like “agile“ development techniques with much interactive communication, such as Scrum.
- Imagine a Principal Investigator acting as a “Scrum Master“.

# https://en.wikipedia.org/wiki/Scrum_(software_development)#/media/File:Scrum_Framework.png



# Scenario 3: Outlook

- On the other hand, new technical developments (e.g., Big Data, distributed processing) and the advancement of science necessitate the solution of highly complicated problems.

- The solutions have to be documented carefully (e.g., for long-term data preservation)

- Open issue: How will the funding agencies react to this challenge?