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An Old/New Approach to Space Flight Missions for Astrophysics: Spiral Development

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Abstract

Spiral Development (Figure 1) is an intuitative, risk-driven process for rapid, agile, iterative development of systems that was originally proposed for software development (Boehm, 1988), but has also been applied very successfully for many complex spacecraft hardware and software systems, including the very first space vehicles. While NASA has subsequently gotten away from this original 'old-space' approach in favor of single launch, on-of-a kind (and far more costly) spacecraft such as JWST, 'new-space' companies such as Planet, SpaceX and Blue Origins have very successfully adopted agile, iterative spiral development approach of Version 1.0, 2.0, etc. spacecraft based on their 'Silicon Valley' roots. Fortunately, NASA has embraced commercial crew and cargo services that provide lower cost and redundant options for space missions in the last few years. And NASA's on-going In-Space Assembled Telescope (iSAT) study is developing the design for a 20-meter space telescope that could achieve the HabEX and LUVOIR mission goals. Here we discuss how the in-space assembly and servicing infrastructures could be used for future large space telescopes that are assembled and serviced in space in stages with periodic upgrades to maintain long-term state-of the art observational capability for space astrophysics.

Rationale for Iterative Development and Evolvable Space Telescopes

When the space age began the late 1950s and early 1960s nearly all space programs consisted of a series of spacecraft (which were really a series of prototypes launched and tested in space to identify the modifications to the next prototype that were needed to correct the problems detected during mission operations (and to enhance spacecraft performance). At that time, NASA's scientists and engineers were learning how to build vehicles to navigate and operate successfully and reliably in a little understood space environment.

This iterative, spiral development process was successfully applied to NASA's early Explorer and Pioneer missions, as well as the Orbiting Astronomical Observatory (OAO), Orbiting Geophysical Observatory (OGO), and Orbiting Solar Observatory OSO satellite programs. In each program, lessons learned during flight were used to upgrade the next vehicle in the series to increase reliability and performance. New technologies were typically flown on these spacecraft in a non-critical role in order to prove them out before incorporation as standard equipment on future versions of the spacecraft.

Unfortunately, NASA, in its maturity, has gotten away from an iterative development approach in favor of on-of-a kind (and far more costly) spacecraft such as Hubble, Chandra and JWST which have much more detailed design, development, fabrication and integration and test phases spanning two decades in order to retire all possible risks before launching a 20-year old design into space to operate for 10 or more years.

Lately, however; NASA has embraced commercial cargo and commercial space in for services in support of standard mission support activities in order to free up resources for exploration missions beyond in Low Earth Orbit (LEO).
Hopefully the space science community will also embrace the use of commercial space services for the assembly and servicing of future space observatories.

Many old- and new-space companies are currently actively developing the technologies and infrastructure that will be used in the next decade and beyond for in-space servicing and upgrading of spacecraft designed to be evolved into far more capable spacecraft . . . much as the Hubble Space Telescope was serviced, repaired and evolved into a far more capable space observatory. In-space assembly and manufacturing capabilities are also currently in development. These capabilities will enable a new era of space telescopes larger than any that can fit within the larges launch vehicle payload fairing, telescopes that can grow in capability and evolve with new instruments designed to answer the questions raised by the latest scientific research.

HST has shown the way to maintain and upgrade a space telescope using the latest technologies to increase its performance and evolve its capabilities . The ISS program has shown us how in-space assembly can be used to create very large space vehicles in many stagesand to upgrade and evolve its capabilities. The ISS also how the cost of a program can be spread out to avoid affordable peaks and valleys in funding that stretch our programs like JWST and run up the cost; and how to build a cadre of scientists and engineers highly skilled and knowledgeable in the design of the station, facilitating its evolution.

Summary

The capability for in-orbit assembly, servicing and evolution of very large, long lived, space observatories will exist in the next decade(s), and should be considered in planning for future astrophysics missions

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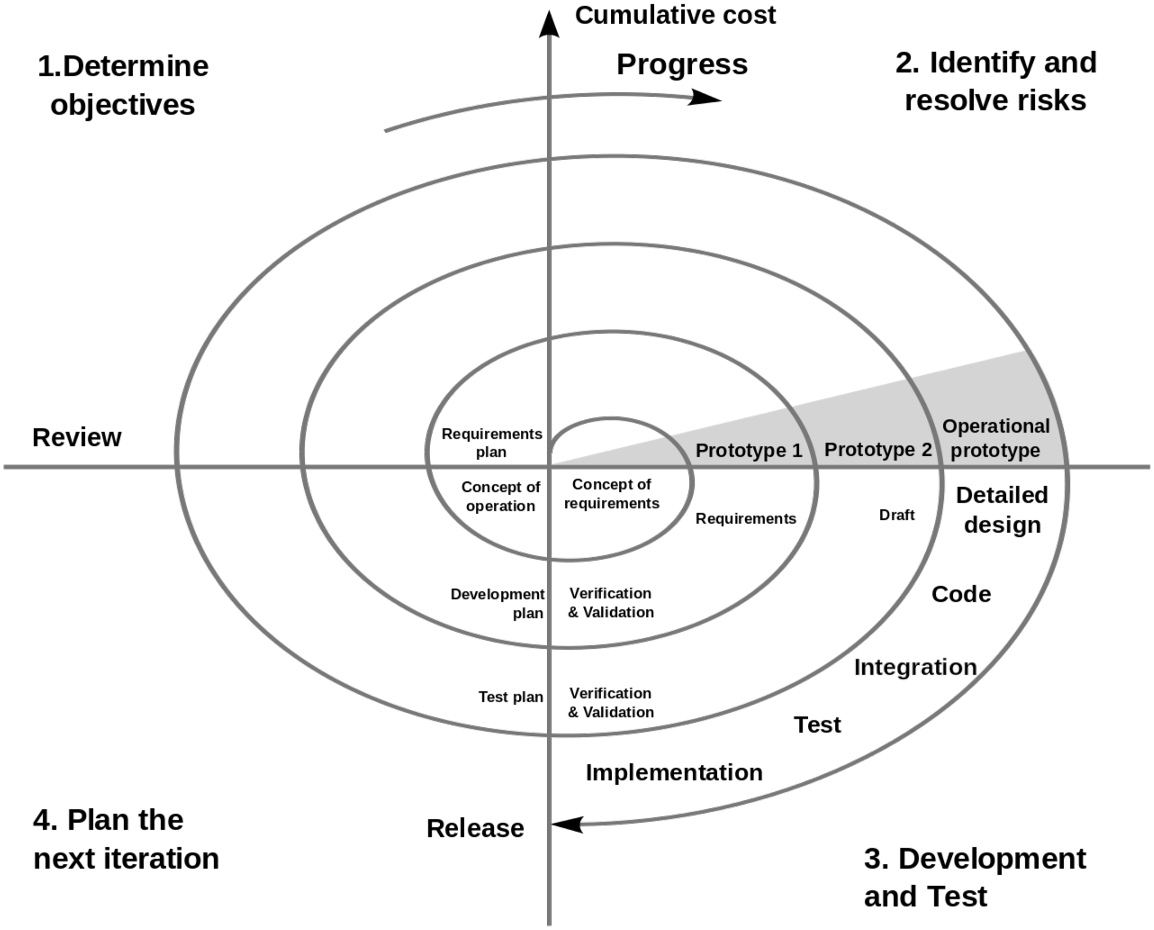

Figure 1. A diagram showing the 4-Steps of Boehm's Spiral Development Model, which also apply to other process models, such as incremental, waterfall, or evolutionary prototyping.