The NPDT - The Next Generation Concurrent Design Approach

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ABSTRACT

The Next Generation Payload Development Team (NPDT), also called Team I, at the Jet Propulsion Laboratory provides a customer with a state-of-the-art Concurrent Design and Analysis environment for the early Design stages that emphasizes a total Systems approach, and features Multi-Disciplinary design teams, and interconnected, high-end Analysis and Design tools. These tools share and utilize a common 3D geometry of payload and spacecraft for their analyses and design. The NPDT provides support for payloads, probes, rovers, and dedicated SC studies and proposals, covering orbital and in-situ types of payloads for volcanic vents off the ocean floor, bore-holes in Antarctica, planetary surface and sub surfaces, Earth and planetary orbits, and atmospheric insertions. According to customers, The NPDT has managed to shrink development time in the early design phases by factors between four and ten.

The concurrent analysis and design method developed and implemented in the NPDT environment can with slight modifications be applied for developing spacecraft, automobiles, oil & gas platforms, and other types of large and complex systems.

INTRODUCTION

At the Jet Propulsion Laboratory (JPL), large resources are put into efforts aimed at improving and changing the organization to effectively deal with developing smaller missions in the hundred million, rather than in the billion dollar range. A large number of these missions are won based on competitive proposals in response to Announcement of Opportunities (AO's) from NASA headquarters. Writing and developing proposals is, therefore, becoming increasingly important for JPL.

In late 1996, it was decided that there was a need for a team that could provide early conceptual design analysis support for payload development and payload proposal work. This led to the development and implementation of the NPDT. Typically, payload or instrument proposals require high degrees of detail in their optical, radiometric, mechanical, thermal, and structural analyses. The NPDT is, therefore, utilizing what is considered high-end tools in its design and analysis work.

The NPDT can be modified both in terms of experts, and in terms of analysis and design tools. This makes it possible to provide development support for support almost any type of space orbital and surface missions (Oxnevad, July, 2000).

This paper starts with a description of the analysis and design methodology utilized in the NPDT, continues with a discussion about its implementation, and ends with some examples of how this methodology has benefitted projects supported by the NPDT.

THE ANALYSIS AND DESIGN METHODOLOGY UTILIZED BY THE NPDT

The analysis and design methodology utilized in the NPDT was developed and refined by the author in close cooperation with engineers and scientists over the last 3–3.5 years. The methodology is based on ideas from concurrent engineering (Oxnevad, 1996), and from what the author in his earlier research has termed concurrent analysis and design (Oxnevad:

The initial version of the NPDT was set up to support optical instrument work (Oxnevad, April, 1998). Later the NPDT has expanded its capabilities to effectively be able to support the development of space payloads, space and sub-sea probes, rovers, and dedicated spacecraft. The current set of high-end tools consequently, includes tools such as Code V™, ZeMax™, TracePro™, MODTool, Mechanical Desktop™ (MDT), Inventor™, Thermal Desktop ™ (TD), MSC Working Model 4D™, and MSC NASTRAN™ for Windows. Most of the NPDT tools are running on PC NT platforms.

NPDT currently includes analysis and design experts in the areas of UV-V-IR optics, micro- and millimeter wave optics, mechanical, thermal, structural/dynamics, electronics/power, mechanical simulations, orbital analysis, radiometry, and costing.

The NPDT environment and process is continuously being updated based on input from NPDT members and NPDT customers.

In its current configuration, the NPDT includes 9 stations, a mechanical/CAD/mechanical simulation station, a thermal station, a structures and dynamics station, an electronics station, an instrument station, a radiometry station, a cost station, an orbital analysis station, and a system station. To improve group interactions, any station's display can be shown on the large projection screen in front of the NPDT room, shown in Figure 1.

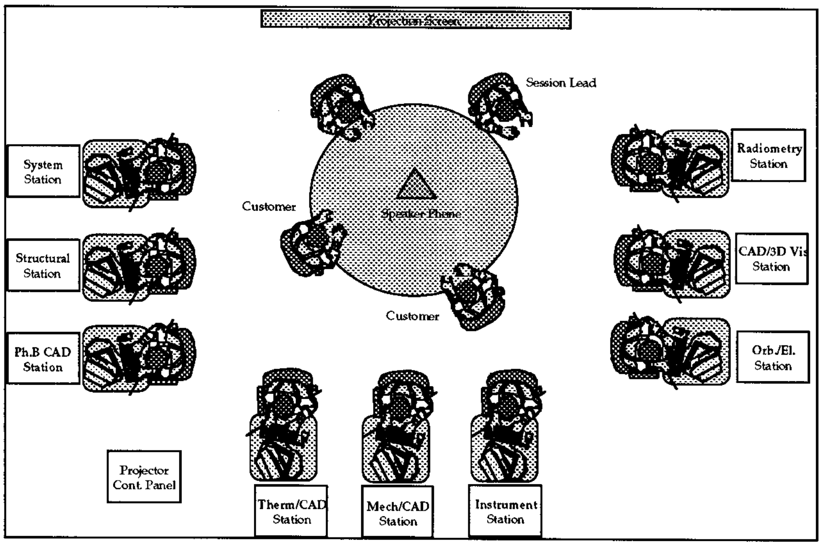

Figure 1: The NGDT Room

The mechanical designer sits at the **mechanical/CAD/mechanical simulation station**. His/her job is to design, modify, and position, the required mechanical configurations. Often this entails importing CAD files of spacecraft, landers, launch vehicles, and specific components, to use as starting points for a design. This brings higher degree of realism into the design, and cuts down on the development time. Most CAD files are imported as STEP files. In the case of optics instruments, the optics configuration and its rays are imported to MDT from ZeMax and TracePro on the optics station as SAT and IGES files. This data is used as a basis for designing, support structures and enclosures required for the optics. Electronics, telecommunication systems, antennas, booms, radiators, etc., are also added to the design at this station. Dimensions, and masses of these components are based on NPDT analyses. From the developed design, preliminary mass, volume, and area estimates can be estimated. For mechanical design work MDT and Inventor™ are being used. At this station, true physical simulations of landers descent, rovers' mobility and stability, and strength of mechanisms to mention a few are also being performed. MSC Working Model 4D™ is used for this work.

At the **thermal station**, a combination of TD and SINDA tools is used. TD uses the geometry developed on the mechanical/CAD /mechanical simulation station together with orbital parameters for calculating orbital heating rates, and for producing radiation interchange factors. SINDA, a thermal analysis program, automatically utilizes these results, together with internal heat dissipation data for calculating temperatures on external and internal surfaces, and components. These temperatures are automatically ported back to TD and displayed on the given CAD geometry. This information is then typically used for discussions about radiator placing, and about whether active or passive cooling is required. The temperature data is also ported to NASTRAN™ via FEMAP™ for thermal deformation analysis.

At the **structures and dynamics station** NASTRAN for Windows™ is being utilized. Typically, launch loads, dynamics loads during operations, natural frequencies for booms, fasteners, supporting structures are calculated here. Input for these analyses are the MDT developed geometry (CAD), materials specs, and environmental data. Such data may be derived from simulations or from launch vehicle specifications. The thermal and structural deformations may be ported directly and electronically to the instrument analysis tools (ZeMax™, Code V™, and MODTool) for real-time structural/thermal deformation impact analyses.

At the **instrument station**, both the UV-V-IR, as well as the micro and millimeter parts of the electromagnetic spectrum are covered.

The (UV, V, IR) optical designer and analyst uses variables such as number of wavelengths, aperture diameter, F#, field of view (degrees), temperature, mirror/lens surface types, and type of mirror material for designing the right optics configuration. The tools Code V and ZeMax are used for this part of the design and analysis work. The geometric representation of the surfaces of the selected optics configuration, together with the geometric representation of the resulting rays are provided as an IGES file. Additionally, the optics configurations itself can be ported to TracePro (ACIS based), also on the optics station, and turned into ACIS based solids and provided as SAT files. These SAT files can be exchanged between any ACIS based programs. MDT is one such program. Cost and mass estimates of the developed optics configuration can also be provided. The ACIS engine is developed by Spatial Technology.

MODTool a physical optics tool is used for the micrometer wave, and millimeter wave analysis. The input variables are basically the same as those used for the UV-V-IR optics analysis.

The optics configuration used for the MODTool analyses is developed in ZeMax™, and then electronically ported to MODTool. This ensures that same geometry is used for the physical optics, mechanical, thermal, and structural analyses and designs.

Structural/thermal deformation impact analyses are performed both with ZeMax™, and with MODTool.

At the **radiometry station**, variables such as required temperature, quantum efficiency, dark current level, detector readout noise, #bits/pixel, aperture diameter, F#, spectral resolution, target scene reflectivity, altitude, number of bands, and observed wavelengths are used for calculating signal to raise (S/N) ratios. The same variables are used for calculating noise equivalent temperature (NEΔT) curves. The tools used for these calculations were developed by the radiometry analyst in Excel spreadsheets.

The work at the **electronics station** includes providing detector information for the radiometry station; defining power dissipation for the electronics components; defining electronics operating temperatures; and calculating data rates, required data storage, required, and processing power. From these numbers, a preliminary component list is put together with component dimensions, and masses and costs. Dimensions and masses are provided to the mechanical/CAD/mechanical simulation station for inclusion in the complete mechanical design. Finally, an electronics block diagram is provided.

The **cost station** is manned by a cost expert that will perform either grassroots costing (costing by analogy) or parametric costing. The parametric cost models take into account factors such as mass, type of technology, development time, and complexity of instrument part. Output from the cost station is fed into the system station.

The capabilities of the Space Orbital Analysis Program (SOAP) is used on the **orbital station** for calculating ground velocity, orbital time, sun exposure on the various sides of a spacecraft/probe, communication time between surface systems and orbiters, sun incidence angle to mention a few. The sun exposure analysis is communicated to the spacecraft, a STEP file of the orbiter correctly dimensioned was imported into the NPDT environment. This gave a clear understanding of available space on the orbiter, and potential FOV conflicts for instruments and radiators. For calculating sun exposure, Jupiter, and Europa exposure, the geometry of the orbiter and the attached payload were ported to the orbital analysis tool. Based on the analysis there, it was determined which sides were less exposed to the sun, and Jupiter. These sides were then used for placing radiators and low temperature detectors. For sizing radiators, a thermal analysis was performed based on the defined orbit, the orbiter, and payload geometries, the defined component temperatures, and the power dissipation from the electronics

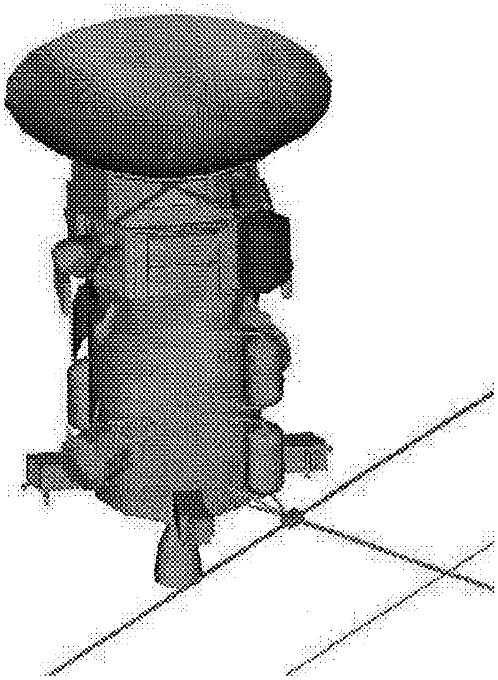

Figure 3: Payload on Europa Orbiter

components. Optical geometries were developed on the optics tool, and packaging based on structural and thermal analysis results was put together on the mechanical station. The starting point for this packaging was the electronically transferred optical configuration from the optics tool. The structural analysis, included launch load analyses of mechanisms, and supporting structures. Electronic block diagrams, mass, power, data rate, data storage, and cost data were also provided.

The NPDT also supported the development of a deep-sea thermal vent optical probe prototype, shown in Figure 4. The probe was designed for being inserted into thermal vents on the ocean floor, down to 8km, looking for life forms at temperatures above 570K. The probe included visual wavelength cameras, UV spectrometers, and lasers. The front-end and back-end optics were developed and packaged by the team. The team also provided support for the packaging of electronics components, cables, and lasers, and fiber optics. This packaging effort had to juggle between very little space, and the need for easy access to optics and electronics. For this design effort, structural analyses were performed on the main housing and the thinner front cylinder of the probe. The geometry developed on the mechanical station was used as basis for these analyses. The turn-around time for this support effort was quite exceptional. Within a week, structural analyses; design of the optics, the probe, cable, and fiber-optic feed-throughs; and packaging had been completed.

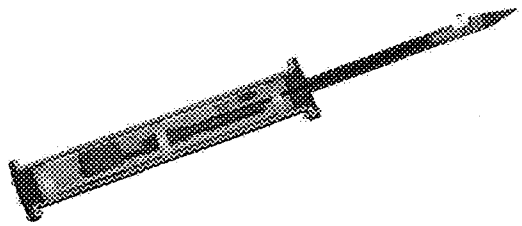

Figure 4: Lohii Type Deep Ocean Volcanic Vent Probe CAD Model

And, within 3 weeks, machine shop-ready engineering drawing had been delivered from the NPDT. This shows that effectively utilizing interconnected high-end tools from the early parts of the design process

Oxnevad, K. I., *A Total Systems Analysis Method, for The Conceptual Design of Spacecraft: An Application to Remote Sensing Imager Systems*, Old Dominion University, Ph.D. Dissertation, May 1996, pp. 18-20.

BIOGRAPHY

Dr. Knut I. Øxnevad currently leads the Next Generation Payload Development Team (NPDT), also called Team I, a leading-edge concurrent design group at the Jet Propulsion Laboratory (JPL). Dr. Øxnevad received his Ph.D from Old Dominion University in 1996. In his research funded by NASA Langley Research Center, he proposed a new design approach for spacecraft. A number of ideas from this research he has later implemented into the NPDT. He is also a graduate of International Space University. Since 1990, he has published 10 papers, completed a dissertation, and given more than 20 talks at institutions and conferences in the US, Europe, and Japan on the topics of concurrent design, collaborative engineering, systems design, design methodologies, and systems analysis. Recently, he was also tasked by NASA Headquarters to talk about his work at the various NASA centers through the NASA System Design (NSD) Program.