A FRAMEWORK FOR COMPLEX SYSTEM DEVELOPMENT

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Abstract

This book outlines a structured framework for complex system design and management. There have been and continue to be many efforts focused on defining the elusive generic System Engineering process. It is suggested that one reason why industry, government, and academic efforts have had limited success in defining a generalized process applicable to many contexts is that the time and logical domains have not been explicitly identified and characterized in distinction. When the logical view is combined with the chronological view, the resulting process often becomes application specific. When these are characterized in distinction, the overall framework is preserved. This book develops a generalized process that maintains this distinction and is thus applicable to many contexts.

The design and management of complex systems involves the execution of technical activities together with managerial activities. Because of the organic connection between these two sets of activities, they must be integrated in order to maximize the potential for success. This integration requires a clear definition of what the system development process is in terms of the technical activities and how they logically interact. In this book, this logical interaction has been defined and is called "control logic." This "control logic" is then used to develop the logical connections and interactions between the managerial and technical activities.

Preface

Several years ago, the author became involved in system engineering process development at General Electric Astro Space (now Lockheed Martin) for two compelling reasons. First, he had been leading a number of advanced spacecraft design studies for various space physics missions and was becoming increasingly frustrated at the lack of order in terms of the flow of activity and information. The work was getting done thanks to excellent subsystem engineers, but there was an appalling lack of order, even chaos to some degree. The author began to see the need to develop a more organized approach to complex system development. His opportunity came in the autumn of 1993 when Astro experienced an unprecedented string of spacecraft failures.

On Saturday, 21 August 1993, contact was lost with the Astro-built Mars Observer spacecraft, just three days before it was to enter orbit around the planet. To the author's knowledge, after intensive investigation, there has been no definitive determination as to the cause of failure. On that same Saturday, NOAA-13, a TIROS weather satellite launched just 12 days prior, experienced a total system failure — most likely the result of an oversize screw that eventually caused the entire electrical power system to fail. About 45 days after that, on 5 October 1993, there was a malfunction during the launch of the Landsat 6 satellite that caused the spacecraft to plunge into the ocean.

In the midst of these failures, Astro was competing for a major low earth orbit spacecraft contract. It was in this context that the opportunity came for the author to join that engineering team for the purpose of developing a sound system engineering approach for the program. He was tasked to develop a structured approach that avoided standard "boiler plate" and reflected how the system would actually be developed in the real world. That was exactly what he wanted to do as a personal goal and professional objective — the second compelling reason he became involved in system engineering process development.

After several months of research, trial-and-error, and prayer, the author developed a new system engineering process that was summarized in the paper, "A New Look at the System Engineering Process — A Detailed Algorithm."[1] That process became the basis for the system engineering

[1] Adamsen, Paul B. Jr., A New Look at the System Engineering Process — A Detailed Algorithm, "Systems Engineering in the Global Market Place," *Proceedings of the Fifth Annual Symposium NCOSE*, Vol. 1, July 22-26, 1995, St. Louis, MO.

training course at Astro, which was taught to several hundred junior and senior engineers. It became the starting point for the author's thesis at MIT, and the seed from which this present work has grown.

This book is intended to provide a *framework* for the design and management of complex systems. It is a generalized *framework*, not an exhaustive exposition. The goal has been to distill the essential aspects of system design into a logical process that accurately reflects what should actually occur on a well-organized development program. This book is relatively brief and succinct, which will hopefully extend its usefulness to busy managers, engineers, and students.

Who should read this book?

- System Engineering Managers
- System Engineers
- Engineers involved in complex system development
- Program Managers
- Senior Managers
- Government Procurement Managers
- Customers
- Proposal Managers
- Engineering Educators and Students
- Research and Development Managers

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I would also like to thank my family: Mr. and Mrs. Paul B. Adamsen, Sr., my mom and dad, for their prayers, encouragement, and love; Mr. and Mrs. Robert M. Kubow, my mother- and father-in-law, for their many acts of kindness and generosity to my children, my wife, and to me; my children

— Paul, David, and Lauren — for their prayers, patience, and love; and my beloved wife, Karen, for her prayers, support, patience, friendship, and love.

Finally, I would like to express thanks to my Lord Jesus Christ, who, in answer to my prayers and the prayers of many of God's people, has given me a measure of understanding in the area of complex system development. *Soli Deo Gloria*.*

* The views expressed are those of the author, and do not necessarily reflect the views of the staff or management of CRC Press LLC.

Dedication

This book is dedicated to my beloved wife and best friend, Karen

and to my children

Paul, David, and Lauren

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Tables and Figures

Tables

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Acronym List

ADACS	attitude determination and control system
AKM	apogee kick motor
ASME	American Society of Mechanical Engineers
Arcmin	arcminute
Arcsec	arcsecond
CAD	computer aided design
CAE	computer aided engineering
CAM	computer aided manufacturing
CCB	configuration control board
C&DH	command and data handling system
CGRO	Compton Gamma Ray Observatory
CMND	command
DP	design parameter
DOD	Department of Defense
DSM	design structure matrix
DSP	defense support program
DSMC	Defense Systems Management College
EIA/IS	Electronic Industries Alliance/Interim Standard
EMC	electro magnetic compatibility
EMI	electro magnetic impulse
EPS	electrical power system
EQFD	enhanced quality function deployment
ERS	earth research satellite
ESAT	example satellite
ETM	engineering test model
FAT	fabrication, assembly, and test
FDIR	failure detection isolation and recovery
FMECA	failure modes effects and criticality analysis
FR	functional requirement
FSS	fine sun sensor

GEOSAT	Geodetic satellite
H/W	hardware
HST	Hubble Space Telescope
Hz	hertz
IEEE	Institute of Electrical and Electronics Engineers
INCOSE	International Council on Systems Engineering
ICD	interface control document
I&T	integration and test
I/F	interface
I/O	input/output
IMU	inertial measurement unit
Kbps	kilobit per second
Km	kilometer
MIT	Massachusetts Institute of Technology
NASA	National Aeronautics and Space Administration
NOCSE	National Council on Systems Engineering
NOAA	National Oceanic and Atmospheric Administration
OBC	on-board computer
OP'S	operations
PDP	product development process
P/L	payload
PRS	propulsion system
QFD	quality function deployment
R&D	research and development
RD	requirements development
RF	radio frequency
RQMT	requirement
RW	rework
RWA	reaction wheel assembly
S/C	spacecraft
SDF	system development framework
SMS	structure and mechanism system
SS	subsystem
S/W	software
TBD	to be determined

TBR	to be reviewed
TBS	to be supplied
TCS	thermal control system
TDRS	tracking and data relay satellite
TDRSS	tracking and data relay satellite system (includes ground terminals)
TDW	tailored document worksheet
TIROS	television infrared observation satellite
TLM	telemetry
TPM	technical performance measure
TSE	total system elements