Introdução a Engenharia de Sistemas Espaciais

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Conteúdo da Apresentação

- Conceitos em engenharia de sistemas;

- Engenharia de sistemas no ciclo de vida de satélites e plataformas espaciais;

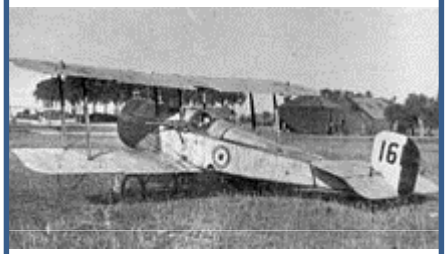
- A atuação do engenheiro de sistemas;

- Sumário das atividades da Divisão de Sistemas Espaciais (DIDSE) do INPE.

A **engenharia de sistemas** surgiu como disciplina devido a necessidade de se *tratar* de forma mais estruturada a crescente *complexidade* de determinados produtos, como aviões e automóveis.

Exemplo de aumento da complexidade em um produto: o avião.

Início 1900s

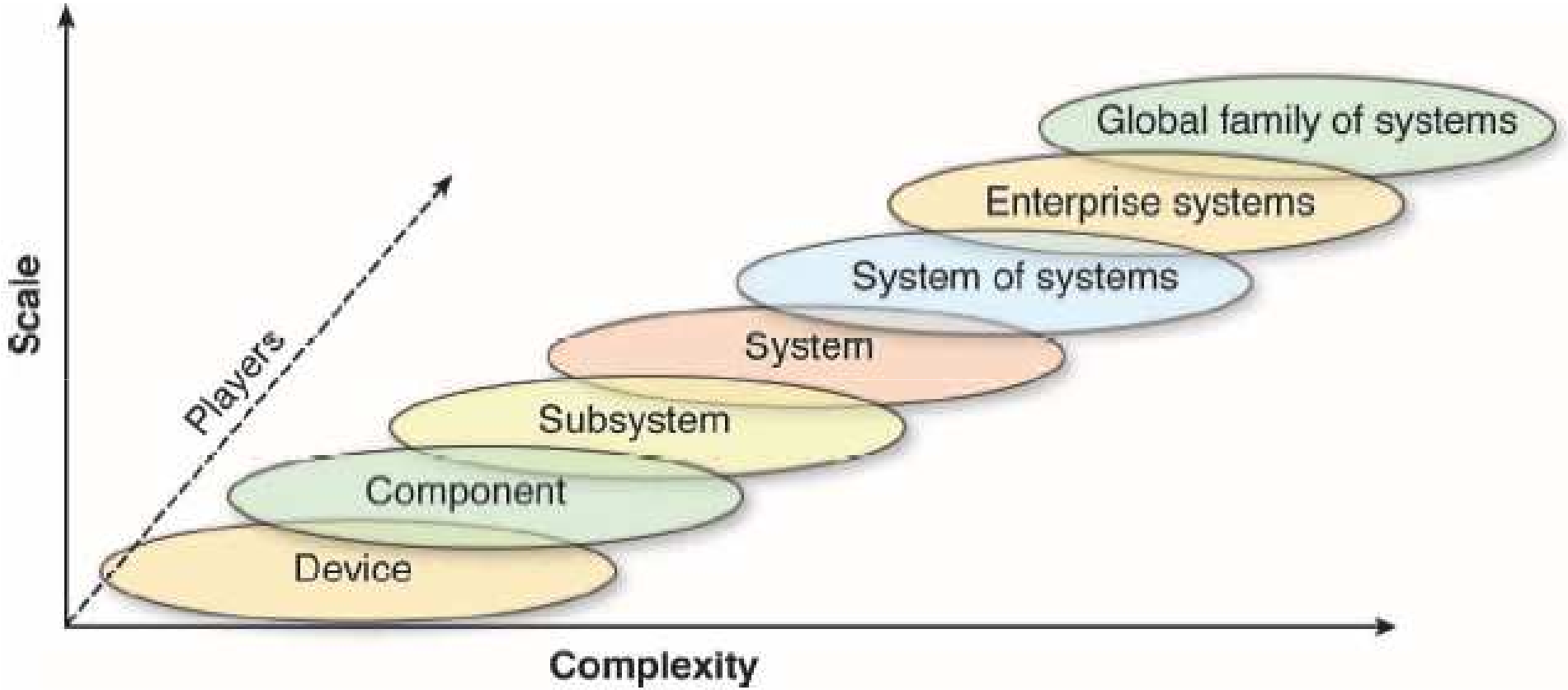


1910s

1940s

1950s aos dias atuais

Fonte das figuras: Wikipedia



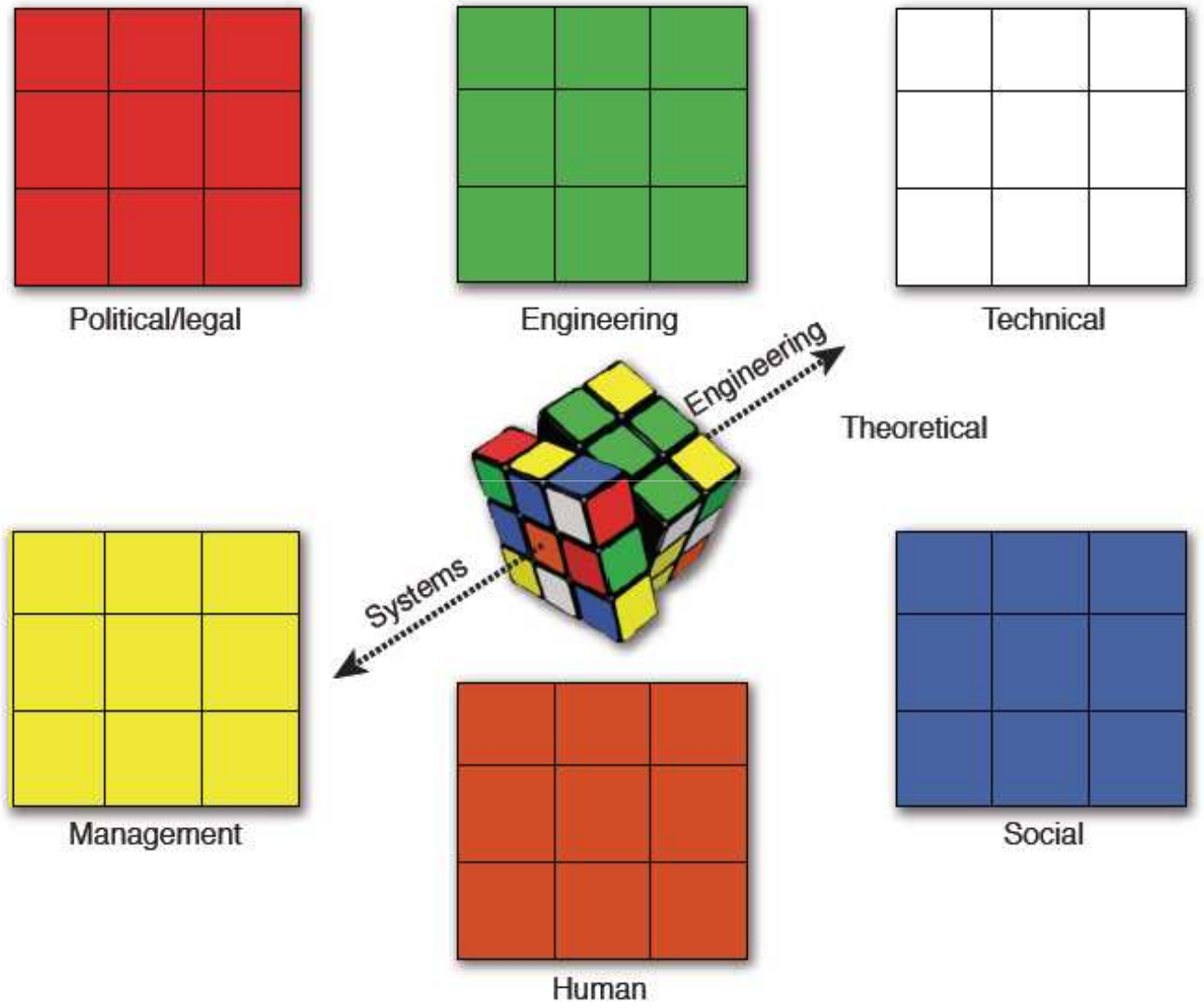
The scope of systems in terms of scale and complexity.

[Seymour et al., 2011]

"A **Engenharia de Sistemas tem um caráter interdisciplinar.** Ela parte da definição das necessidades do cliente e funcionalidade requerida para o sistema, desde o princípio do seu desenvolvimento, documentando requisitos, e então procedendo para o projeto, desenvolvimento e validação daquele, considerando o problema completo: operação, custo, cronograma, performance, treinamento, suporte, teste, fabricação e descarte. A Engenharia de Sistemas considera tanto as necessidades técnicas quanto de negócios de todos os clientes, com o objetivo de prover um produto de qualidade que atenda as necessidades de seus usuários." [Incose, 2011]

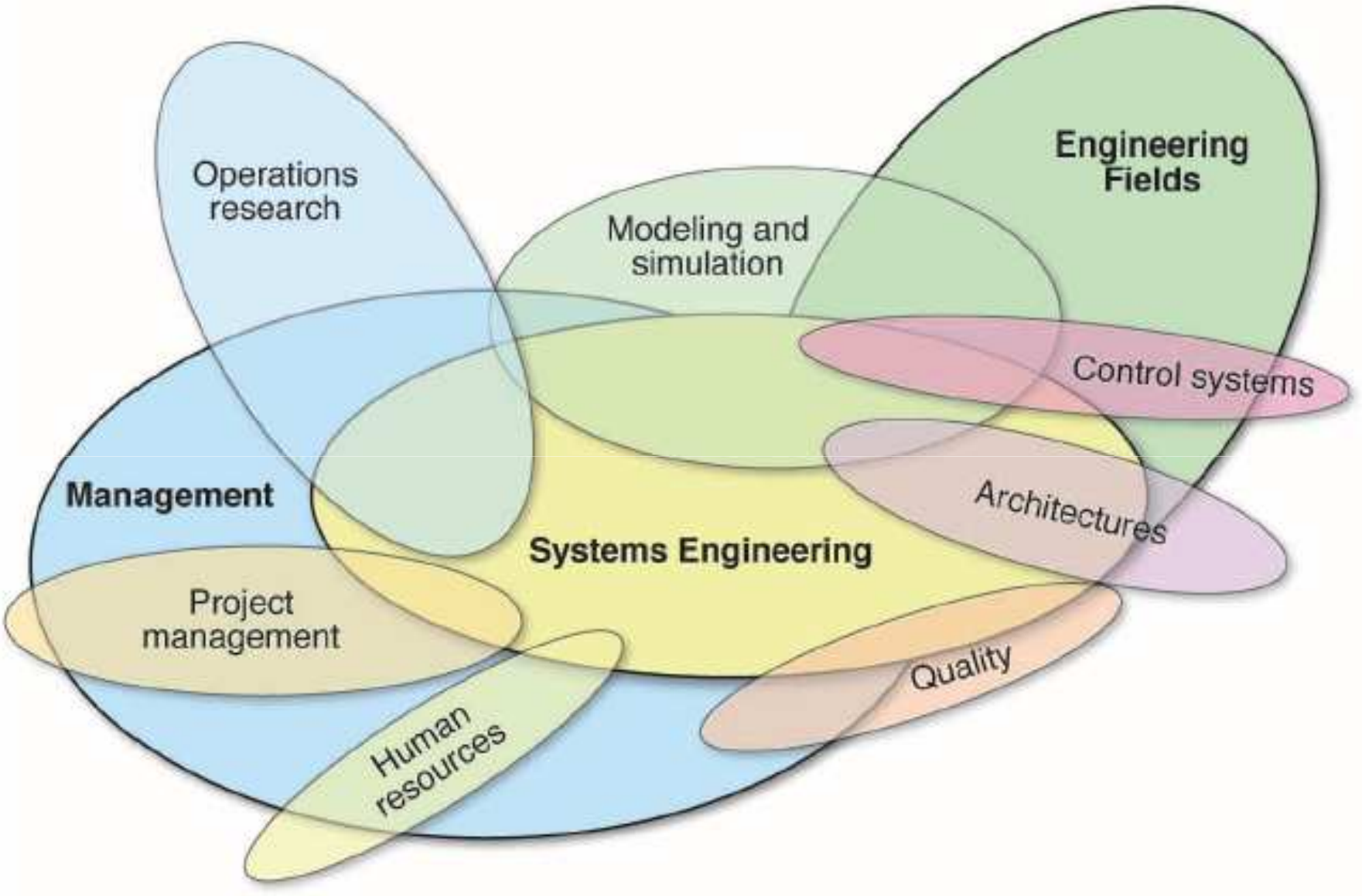
"**Systems engineering is a methodical, disciplined approach for the design, realization, technical management, operations, and retirement of a system."** [NASA, 2007]

"…interdisciplinary approach governing the total technical effort required to transform a requirement into a system solution." [ESA, 2009]



Systems engineering domains.

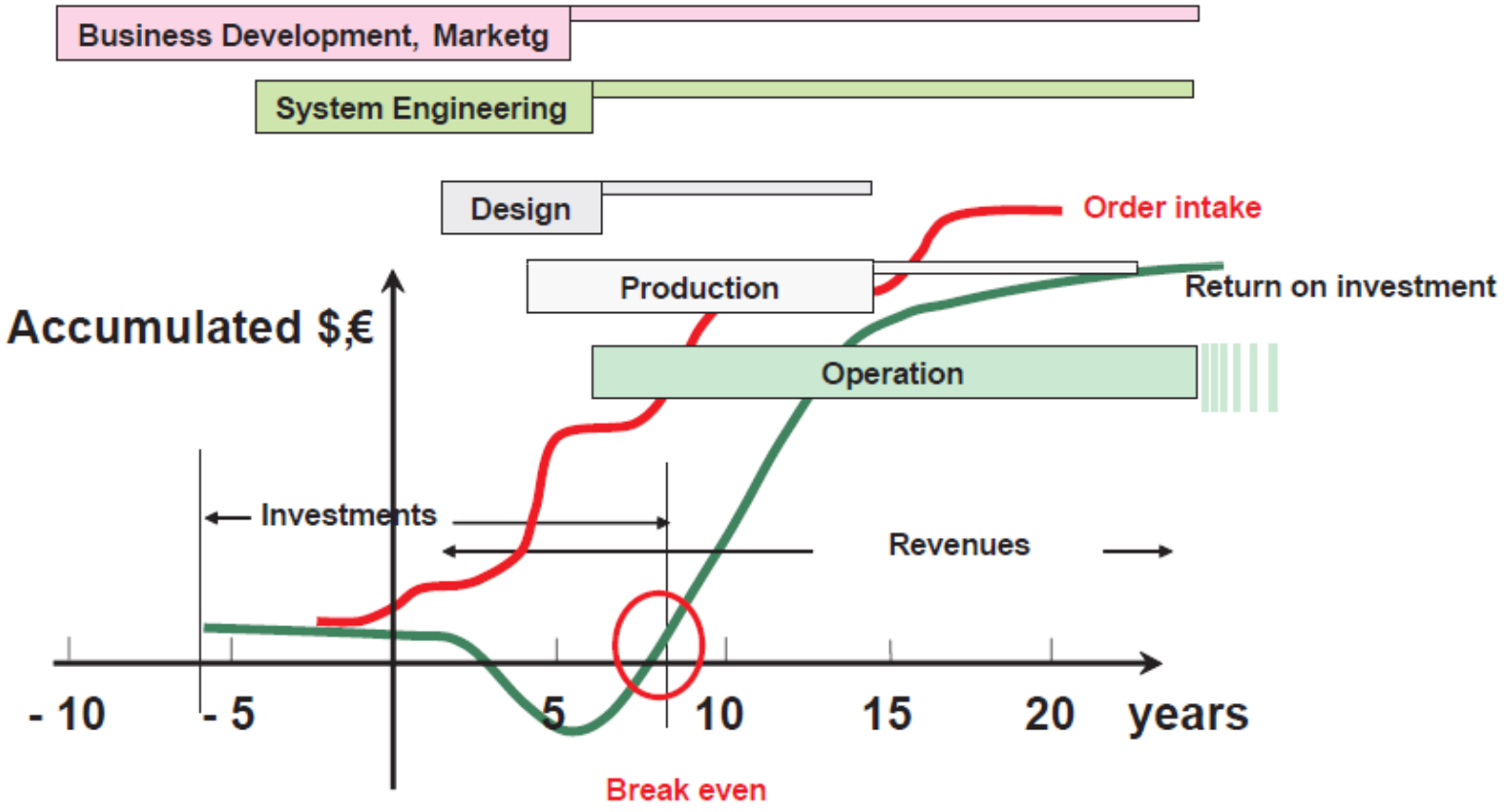
[Seymour et al., 2011]



The interfaces of systems engineering to other fields.

[Seymour et al., 2011]

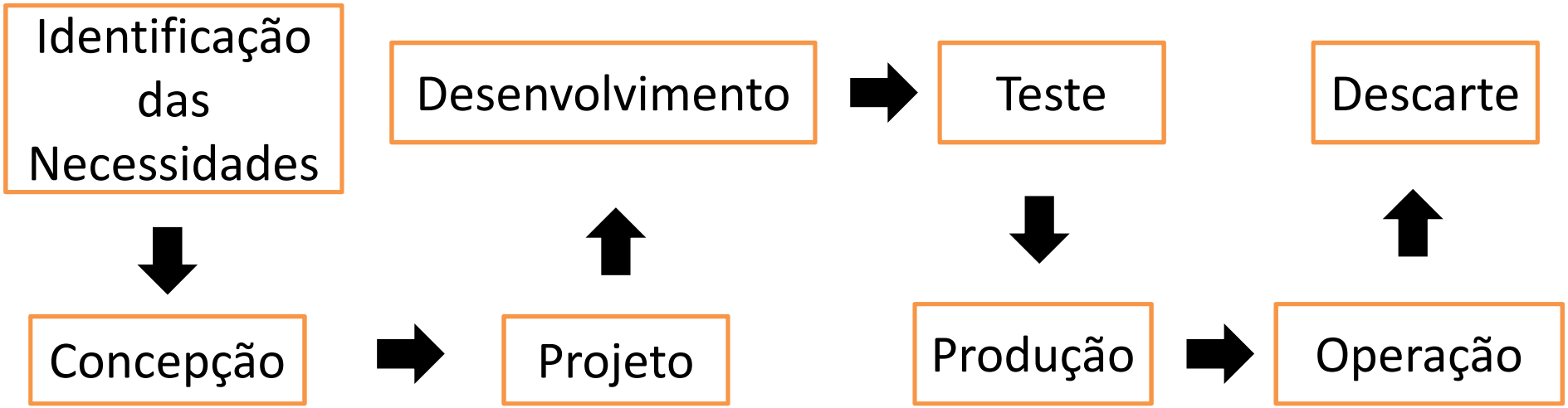
As atividades de Engenharia de Sistemas estão mais concentradas no início do ciclo de vida do produto, mas elas ocorrem em todas as suas fases.

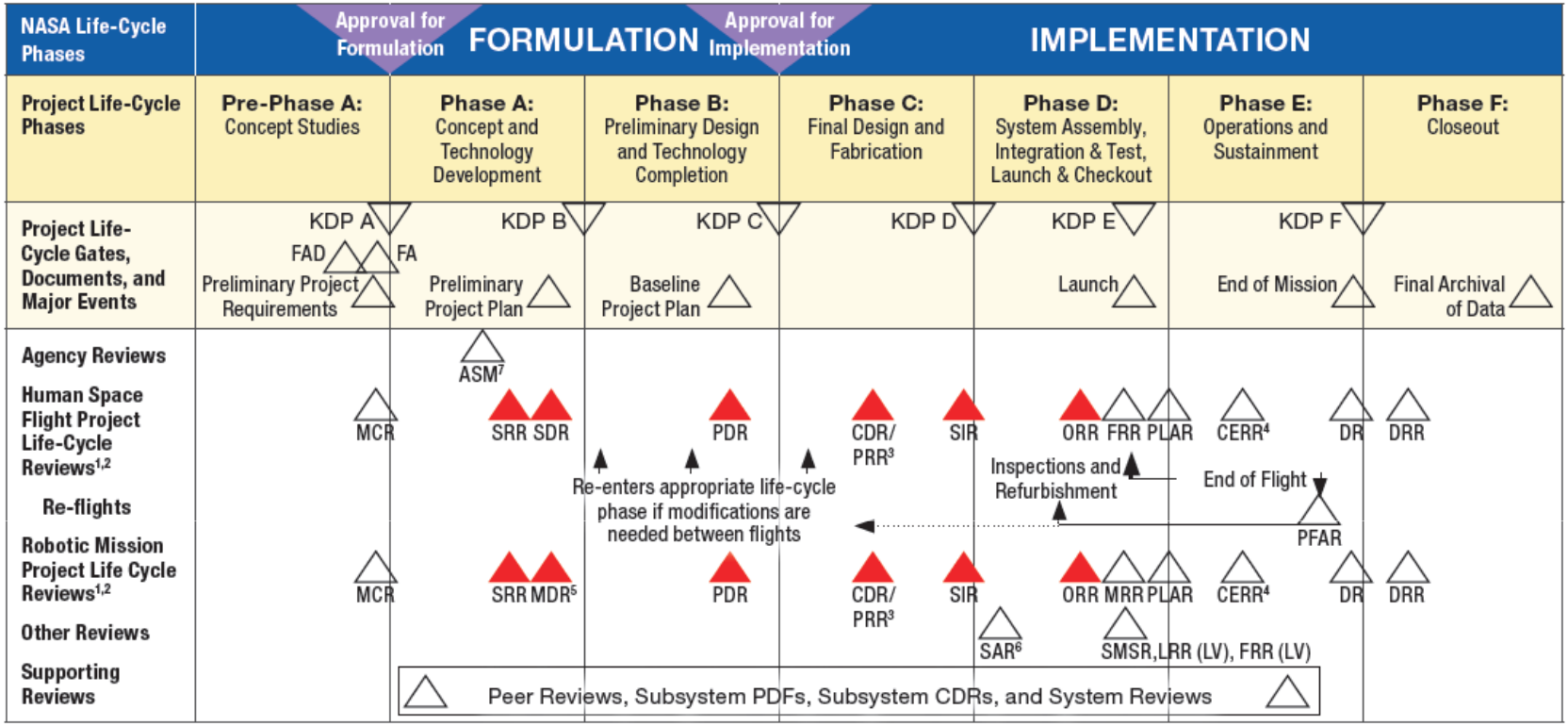


Generic Business Life Cycle

[Incose, 2011]

REPRESENTAÇÃO *SUPER* SIMPLIFICADA DAS FASES DO CICLO DE VIDA DE UM PRODUTO





FOOTNOTES

1. Flexibility is allowed as to the timing, number, and content of reviews as long as the equivalent information is provided at each KDP and the approach is fully documented in the Project Plan.
2. Life-cycle review objectives and expected maturity states for these reviews and the attendant KDPs are contained in Table 2-5 and Appendix D Table D-3 of this handbook
3. PRR is needed only when there are multiple copies of systems. It does not require an SRB. Timing is notional.
4. CERRs are established at the discretion of program .
5. For robotic missions, the SRR and the MDR may be combined.
6. SAR generally applies to human space flight.
7. Timing of the ASM is determined by the MDAA. It may take place at any time during Phase A.

▲ Red triangles represent life-cycle reviews that require SRBs. The Decision Authority, Administrator, MDAA, or Center Director may request the SRB to conduct other reviews.

ACRONYMS

ASM – Acquisition Strategy Meeting
CDR – Critical Design Review
CERR – Critical Events Readiness Review
DR – Decommissioning Review
DRR – Disposal Readiness Review
FA – Formulation Agreement
FAD – Formulation Authorization Document
FRR – Flight Readiness Review
KDP – Key Decision Point
LRR – Launch Readiness Review
LV – Launch Vehicle
MCR – Mission Concept Review
MDR – Mission Definition Review
MRR – Mission Readiness Review
ORR – Operational Readiness Review
PDR – Preliminary Design Review
PFAR – Post-Flight Assessment Review
PLAR – Post-Launch Assessment Review
PRR – Production Readiness Review
SAR – System Acceptance Review
SDR – System Definition Review
SIR – System Integration Review
SMSR – Safety and Mission Success Review
SRB – Standing Review Board
SRR – System Requirements Review

FIGURE 3.0-1 NASA Space Flight Project Life Cycle from NPR 7120.5E

Fonte: NASA Systems Engineering Handbook NASA SP-2016-6105 Rev2

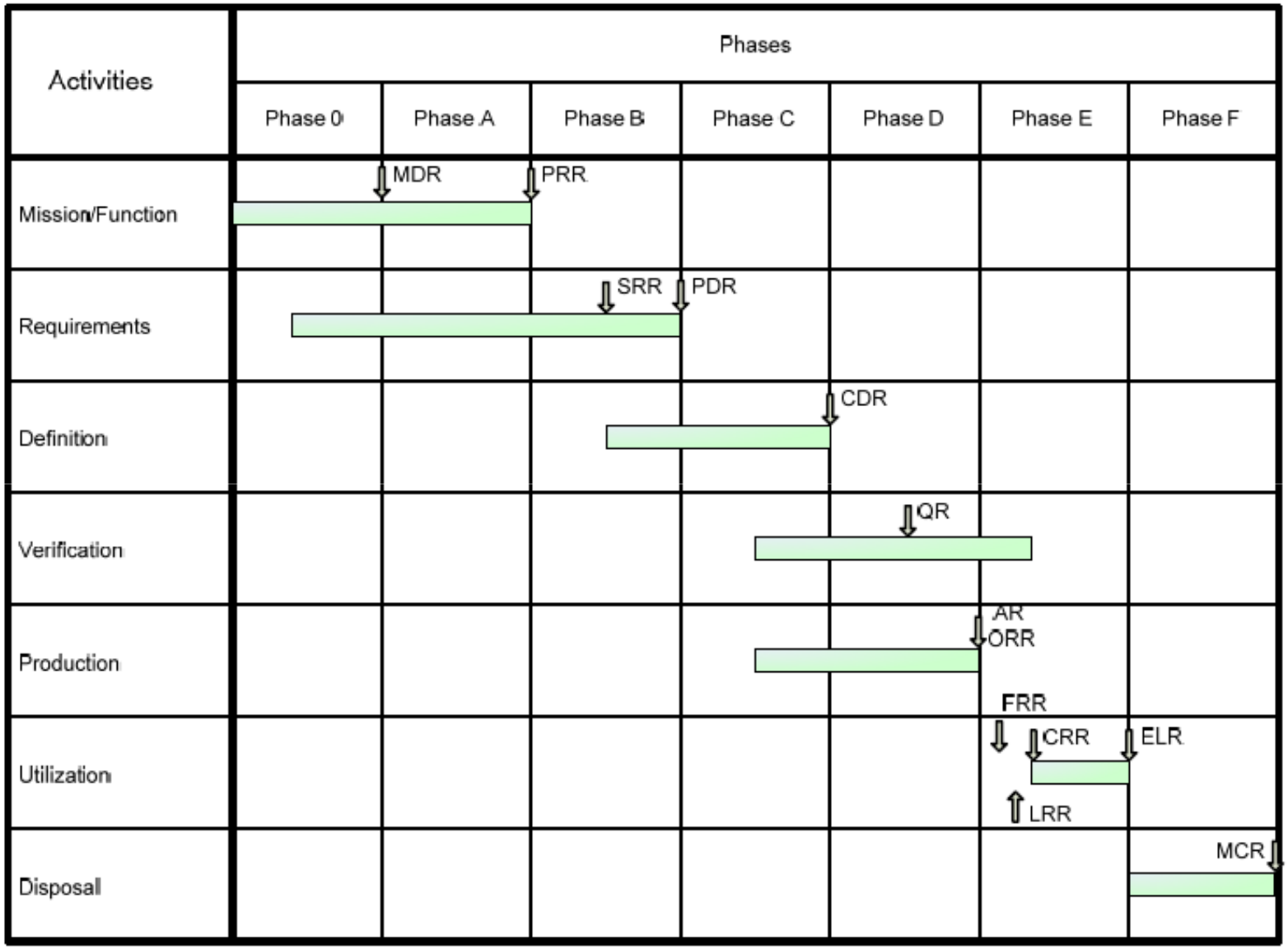
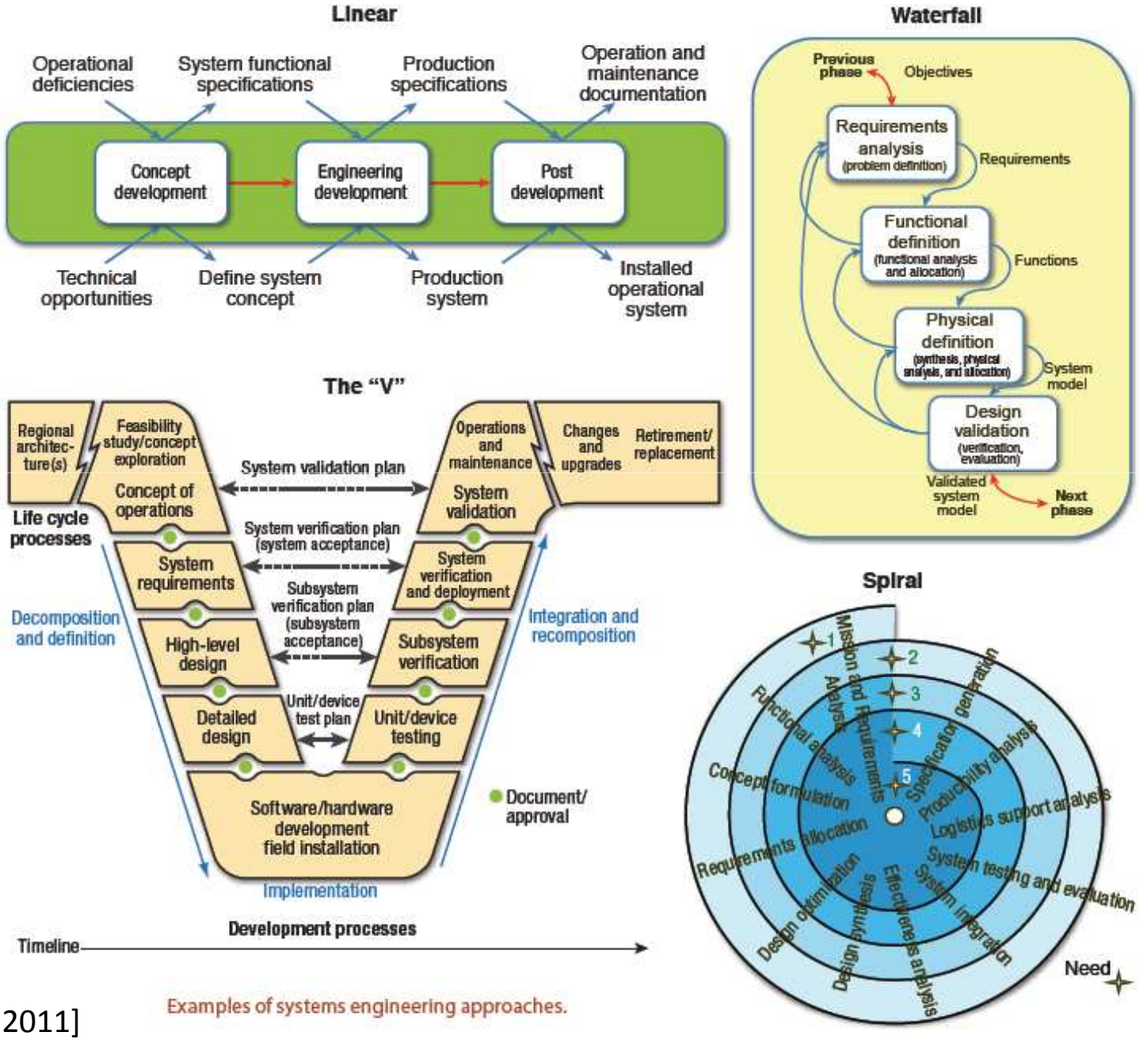


Figure 4-3: Typical project life cycle

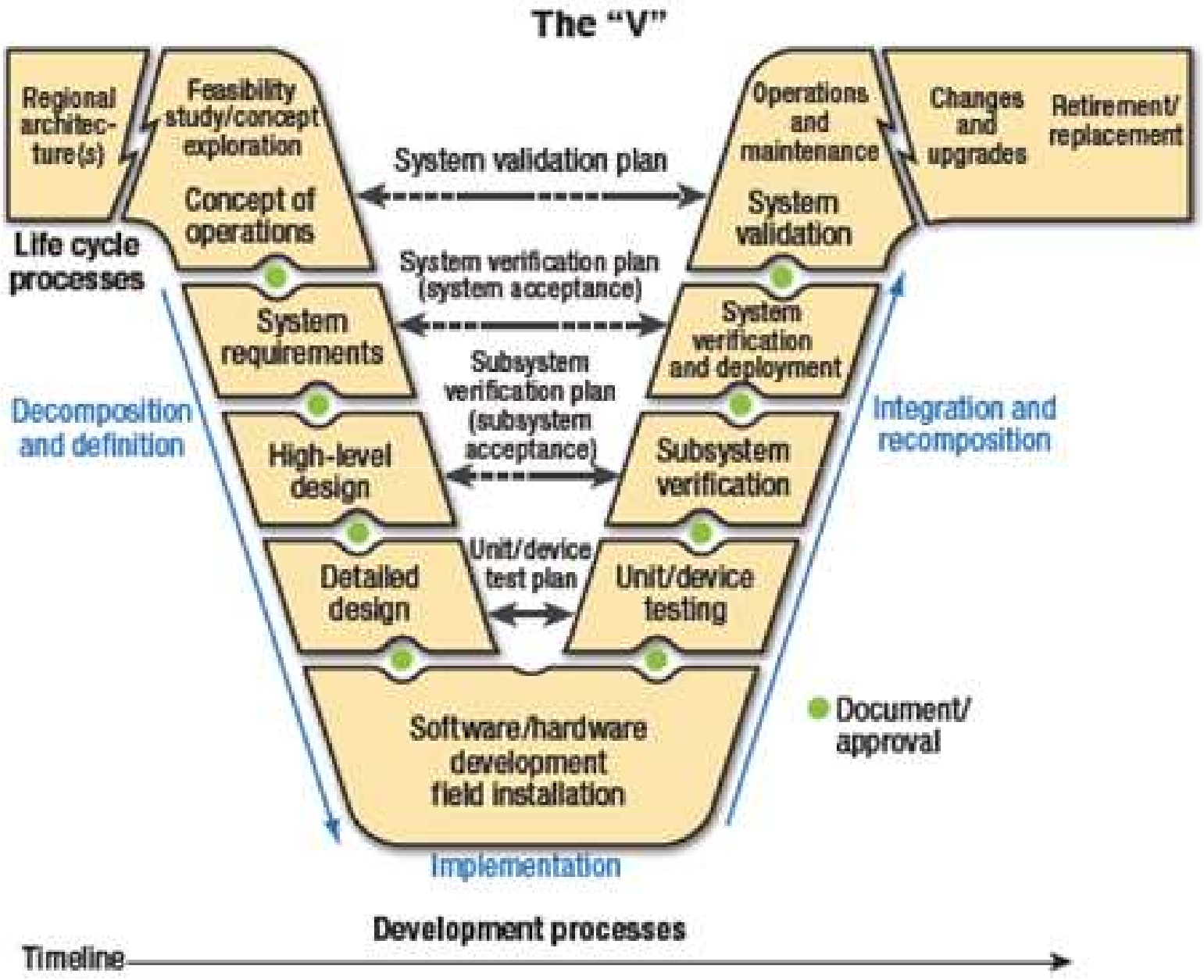
Ref.: ECSS-M-ST-10C Ver.1, 2009

Modelos do Processo de Desenvolvimento do Produto



Examples of systems engineering approaches.

[Seymour et al., 2011]



[Seymour et al., 2011]

"**The role of the systems engineer encompasses the entire life cycle for the system-of-interest**. Systems engineers orchestrate the development of a solution from requirements determination through operations and system retirement by assuring that domain experts are properly involved, that all advantageous opportunities are pursued, and that all significant risks are identified and mitigated. The systems engineer works closely with the project manager in tailoring the generic life, including key decision gates, to meet the needs of their specific project."

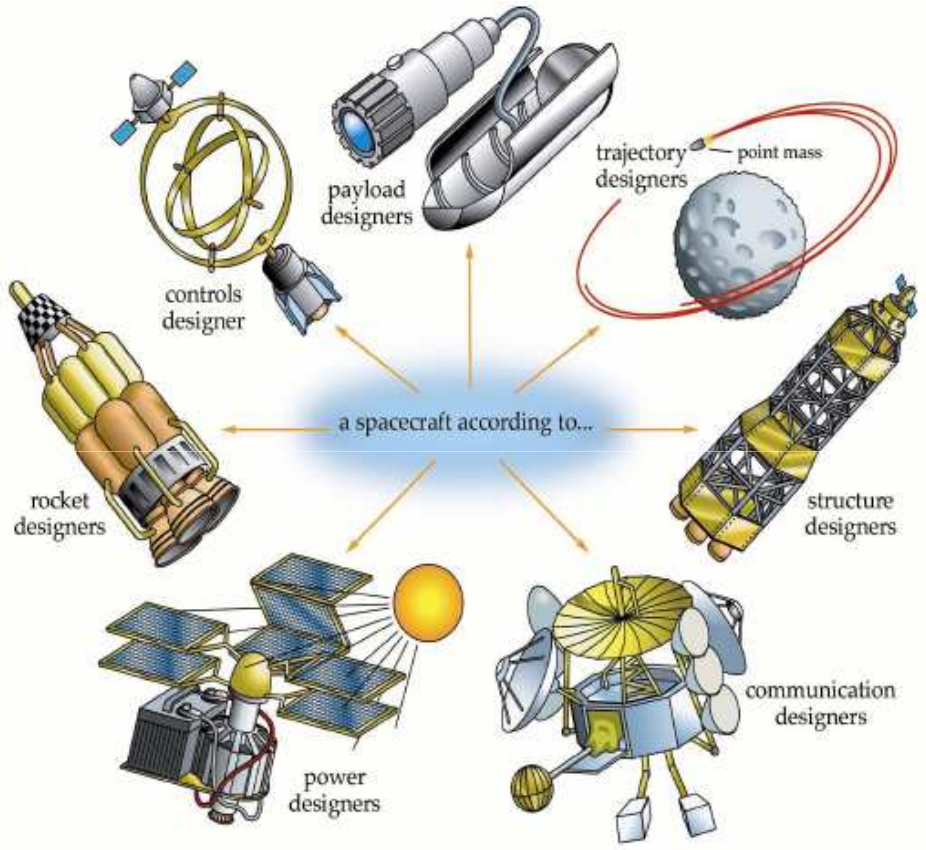
[Incose, 2011]

"O engenheiro de sistemas deve ver/cuidar do todo, não apenas de partes específicas do sistema."

"O engenheiro de sistemas coordena as atividades realizadas pelo time técnico, direcionando, comunicando e monitorando tarefas."

"O engenheiro de sistemas revisa e avalia os aspectos técnicos do projeto, para garantir que os processos de engenharia entre os subsistemas funcionem adequadamente na evolução do sistema da concepção ao produto."

"Todo o time técnico é envolvido no processo de engenharia de sistemas."



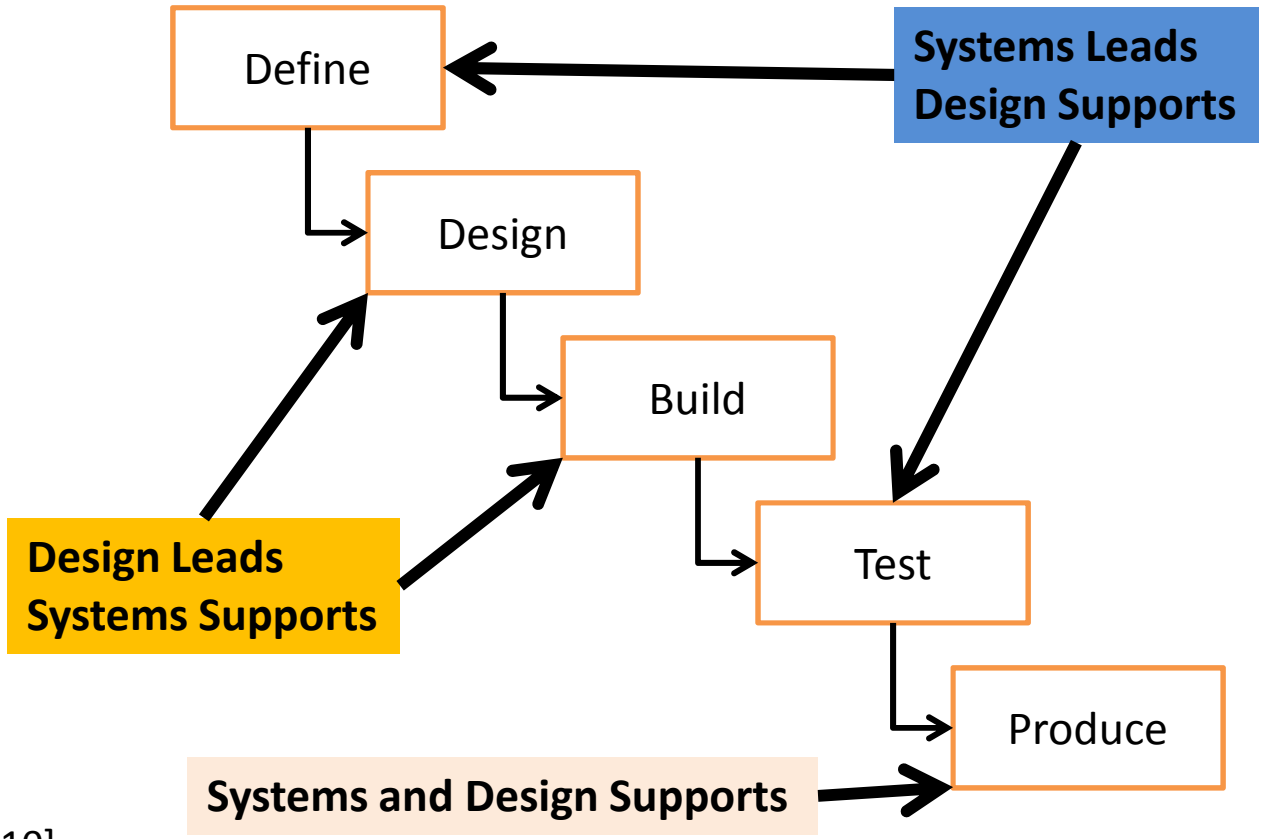
[fig.: Larson, 2010]

[NASA, 2007]

"The fundamental product development tasks should be allowed to overlap in time"

"All engineers do some systems engineering work and most engineers do some design engineering work"

"It is critical to understand that both systems engineers and design engineers are involved in all five phases"



[Jenney, et al. 2010]

Algumas Características e responsabilidades de um(a) engenheiro(a) de sistemas:

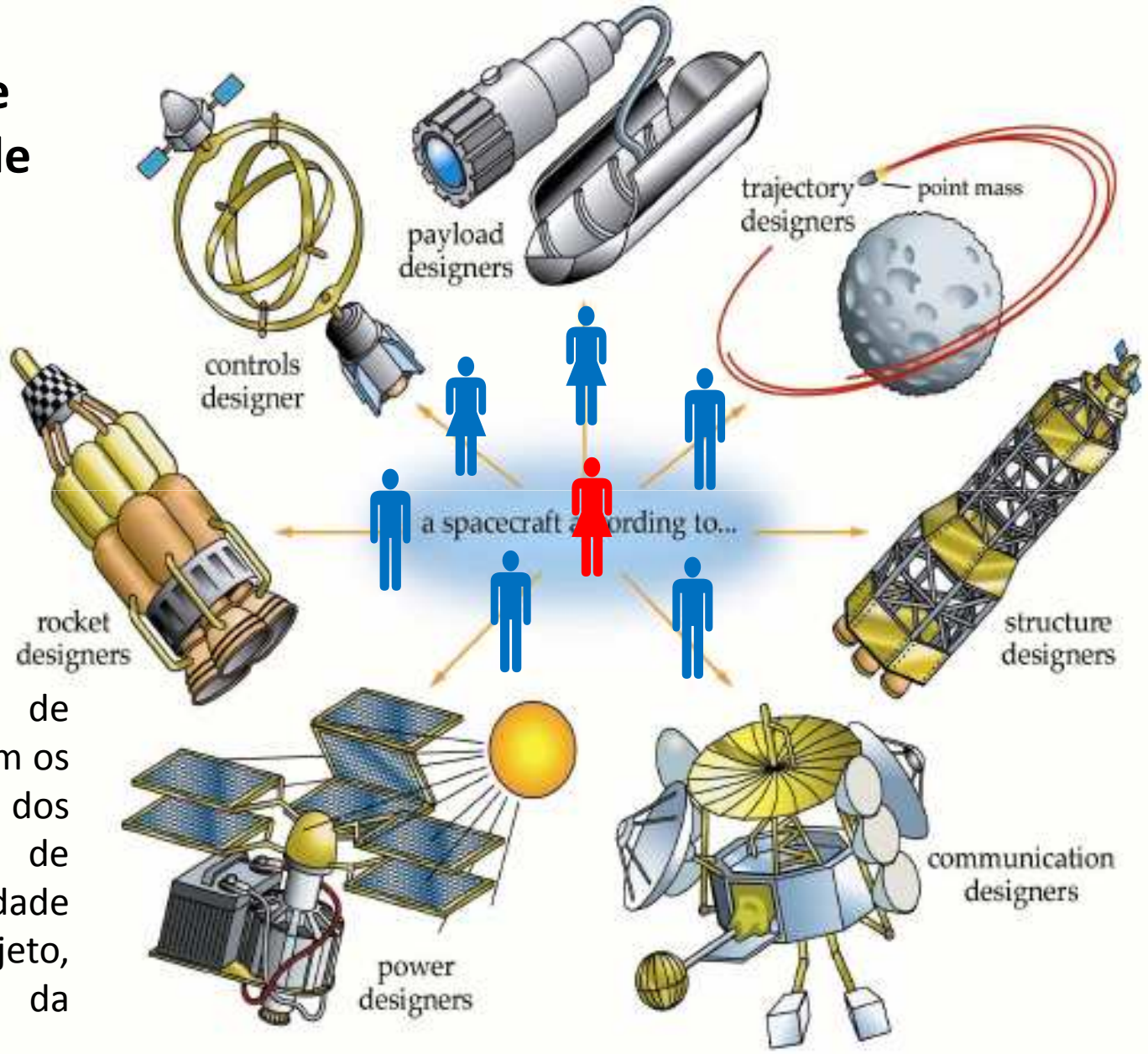
- Bom fundamento nas ciências básicas (matemática, física, etc);
-Ter domínio de pelo menos uma disciplina técnica e conhecimento geral das outras relacionadas ao sistema em que ele(a) atua;
- Curiosidade intelectual, desejo e habilidade de aprender novas coisas;
- Capacidade de entendimento do todo e de comunicar os objetivos do projeto para um time multidisciplinar;
- Estar confortável com mudanças e incerteza;
- Garantir a troca de informação de forma coerente entre diferentes disciplinas;
- Responsável pela integridade técnica do sistema;
- Organizar e liderar times multidisciplinares.

[Ryschkewitsch et al., 2009]

Atuação de um time de engenheiro(a)s de sistemas:

Arquiteto(a)s

Eng. Chefe



O time de engenheiro de sistemas faz a interface com os times de engenharia dos subsistemas (designers) de forma a garantir a integridade e balanceamento do projeto, atendendo os objetivos da missão.

"**In summary**, the systems engineer is skilled in the art and science of balancing organizational and technical interactions in complex systems. However, since the entire team is involved in the systems engineering approach, in some ways everyone is a systems engineer. Systems engineering is about tradeoffs and compromises, about generalists rather than specialists. **Systems engineering is about looking at the "big picture" and not only ensuring that they get the design right (meet requirements) but that they get the right design."**

[NASA, 2007]

"**Model-based systems engineering (MBSE) is the *formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases.*" INCOSE SE Vision 2020 (INCOSE-TP-2004-004-02), Sept 2007**

Use **MBSE** with modern Modeling and Simulation

Establish **Design Command Centers** and ICE Process

"**Implementing ICE allows system development teams to function similarly to the model of chief designer and draftsman/assistant team popular before the emergence of modern complex systems in the 1960s. ...This may be as near to the efficiency of the craftsman model as can be expected for the development of complex systems.**"

Use **PBSE** at Sys., Subsys. & Assembly Levels

Lead by a Chief Designer

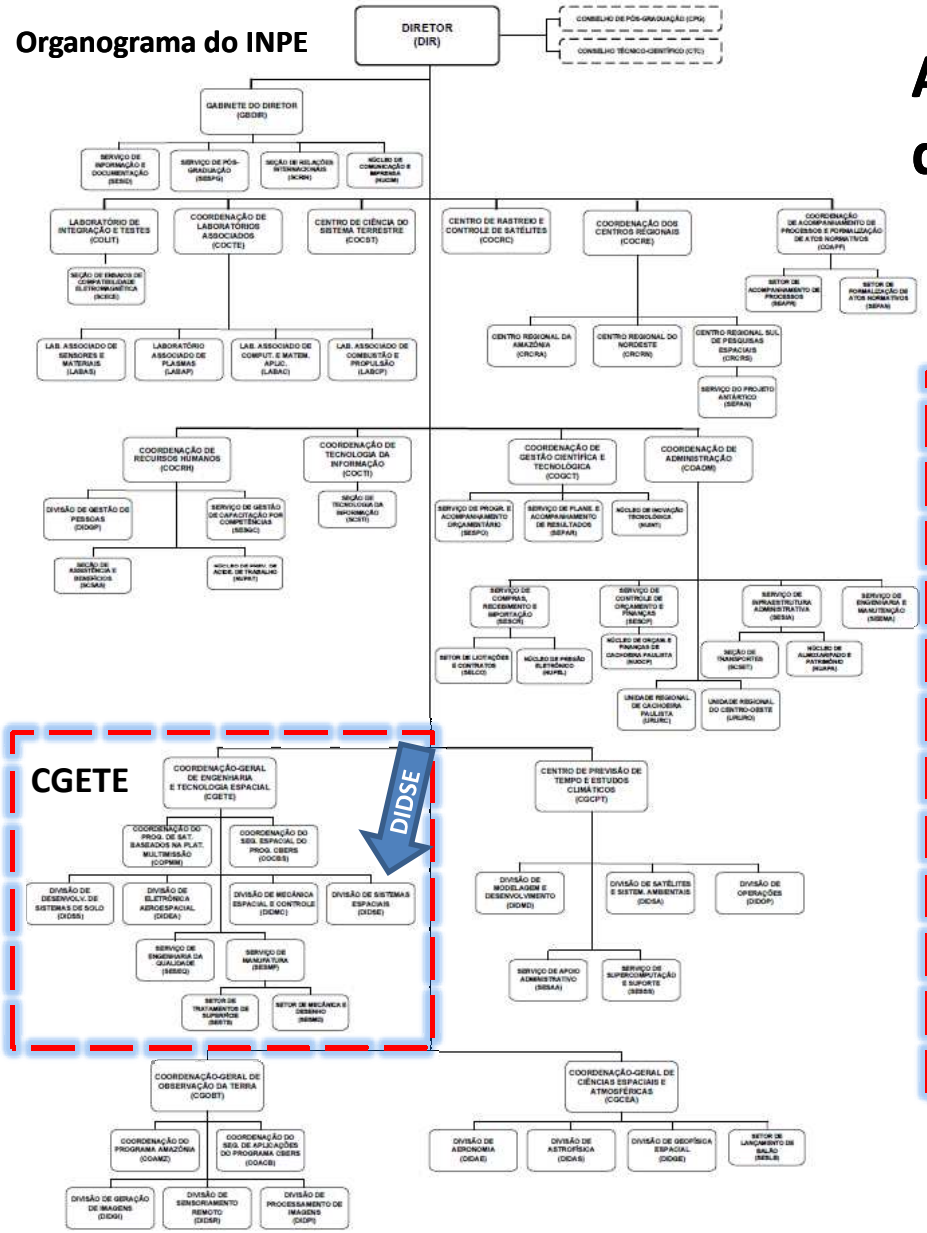
21st Century System Development

Patern Based System Engineering is a methodology of developing and exploiting past solutions for new systems engineering tasks in a standard way that allows systems engineers to reuse and share past solutions."

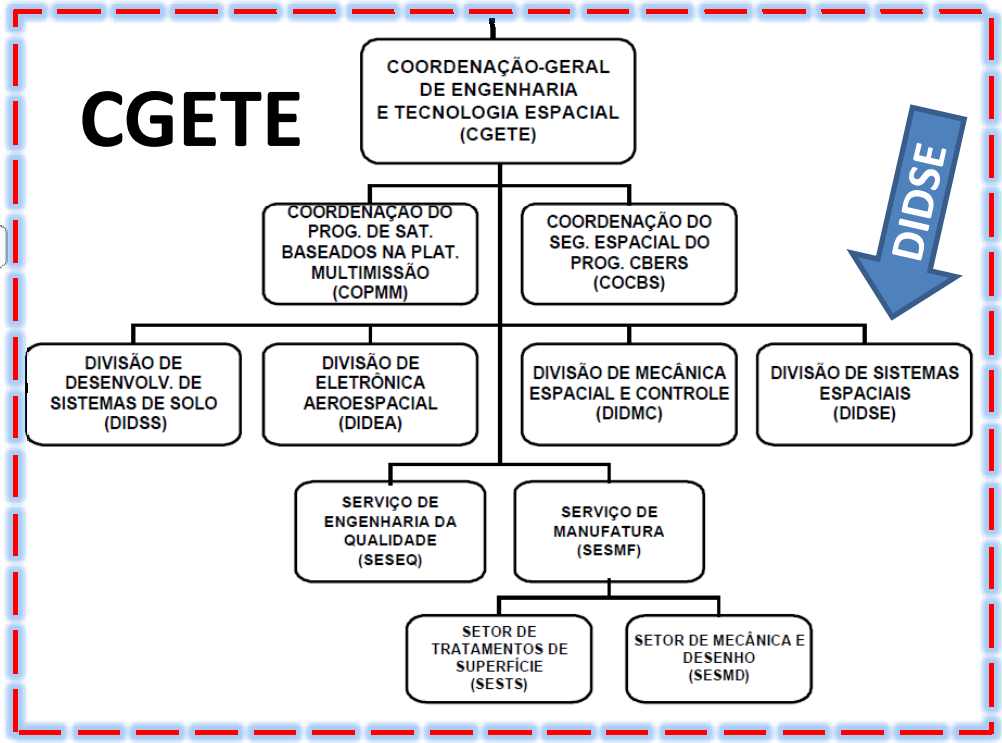
[Jenney, et al. 2010]

Sumário das atividades da Divisão de Sistemas Espaciais do INPE

Organograma do INPE



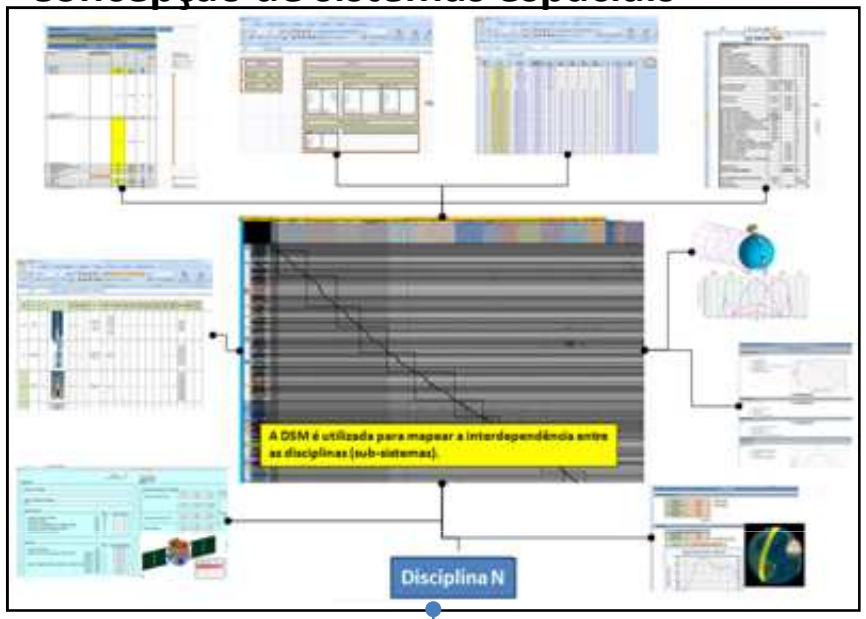
A DIDSE na estrutura organizacional do INPE



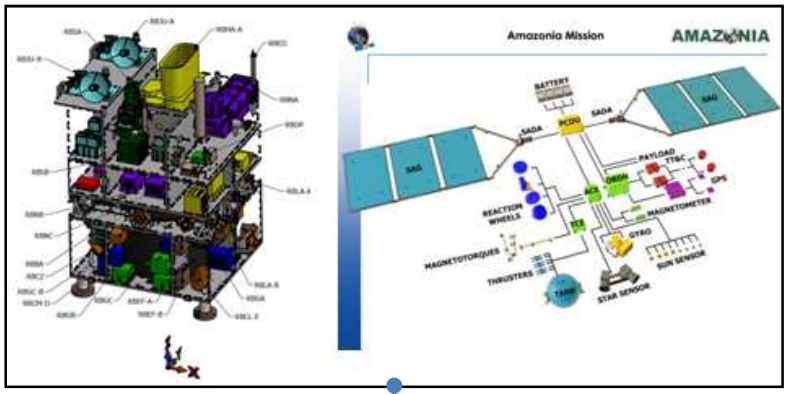

Docência, orientação e/ou co-orientação de dissertações e teses
Programas de satélies
• CBERS;
• Amazônia;
• Equars;
• Avaliação/concepção de sistemas para novas missões.
Acadêmica
Atuação da DIDSE
P&D&I
• Coordenação do curso de inverno em tecnologia e engenharia espaciais;
•Participação em comissões;
•Palestras de divulgação.
Extensão
• Desenvolvimento de processos e ferramentas computacionais em suporte as suas atividades

Núcleos de competência da Divisão

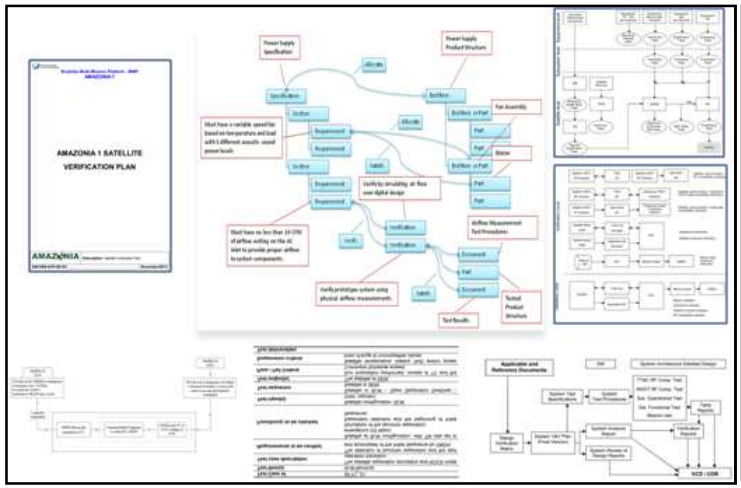
Concepção de sistemas espaciais

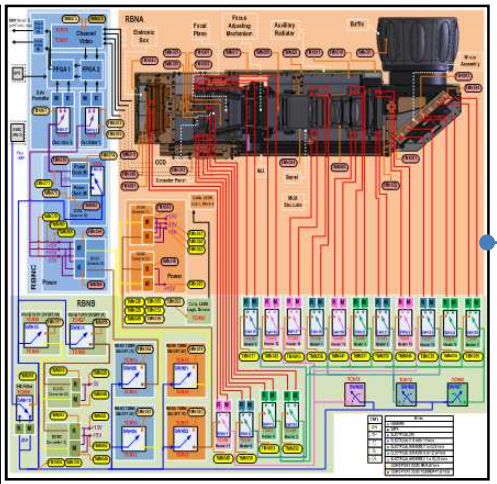


Arquiteturas

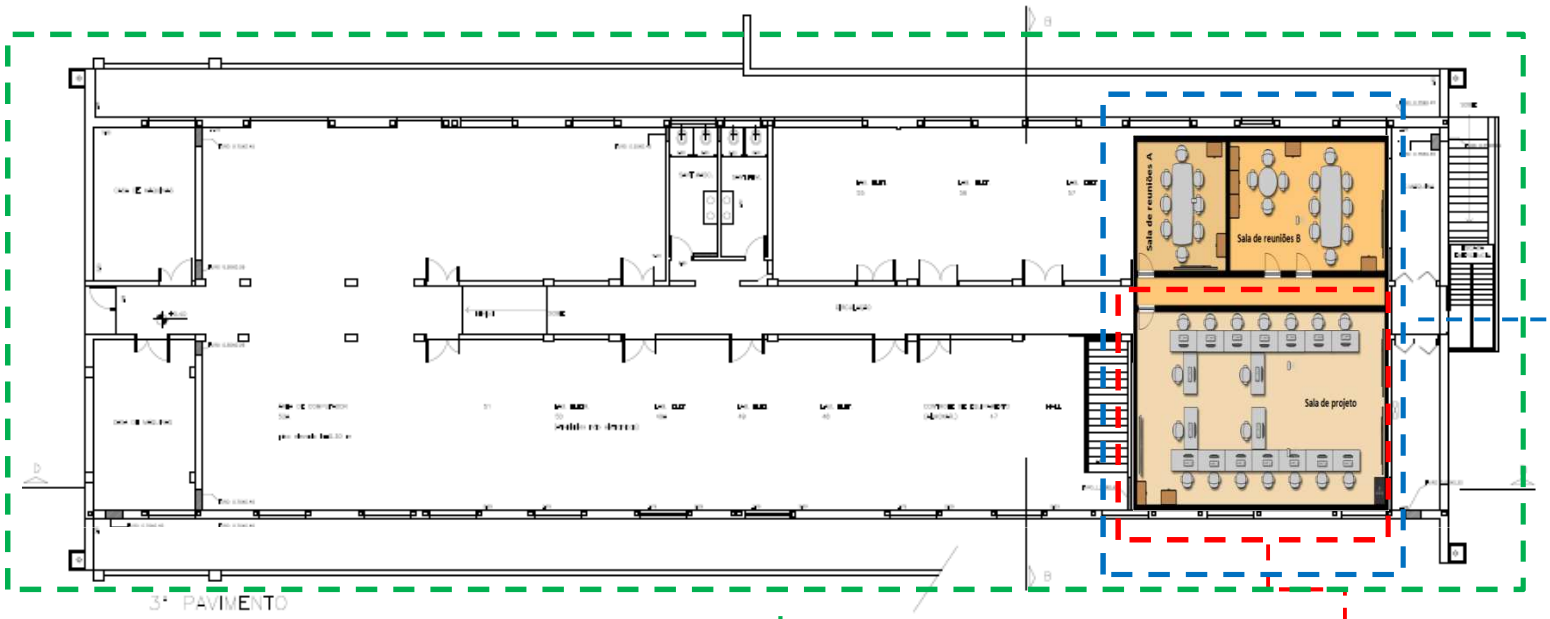


Verificação&Validação





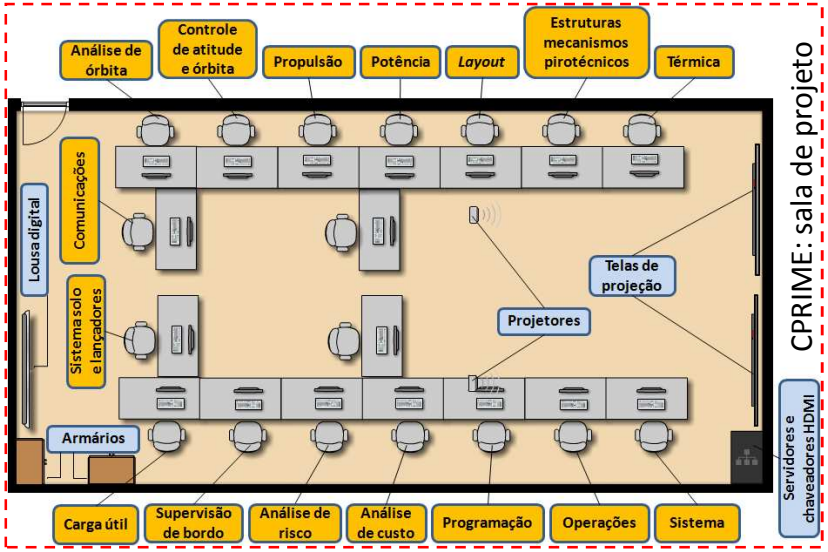
Modelagem e simulação em engenharia de sistemas espaciais, tem um caráter habilitador para tornar eficiente as outras competências essenciais.



CPRIME

A DIDSE localiza-se no 3º pavimento do prédio Beta.

A Divisão abriga o Centro de Projeto Integrado de Missões Espaciais (CPRIME).



➔A DIDSE atua fortemente em todas as fases do ciclo de desenvolvimento (Fases 0-D), e sob demanda no suporte as atividades de operação e descarte (Fases E e F).

➔Normativamente, segue os processos, com adaptações, adotados pela ESA (normas ECSS) e NASA.

Atua em todos os programas de satélites e na concepção de novas missões

- Novas Missões (CPRIME)
- China-Brazil Earth Resources Satellite (CBERS)
- Amazônia-1
- EQUARS

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