TE-265 – MODEL BASED SYSTEMS ENGINEERING

Prof. Dr. Christopher Shneider Cerqueira

2025

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- 1998-2003 - Professional Course on Industrial Informatics – ETEP
- 2005-2011 – Bachelor on Computer Engineering – UNIFEI
- 2012-2014 – Master on Space Engineering and Technology – INPE
- 2014-2028 – PhD on Space Engineering and Technology – INPE
- 2018-2025 – Professor at ITA

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- Collaboration:
  - w/ CONCEPTIO LAB at ITA
  - w/ Projects related to BR-SE Partnership

Complex Systems Design Research Laboratory

Technical Support to FAB Projects

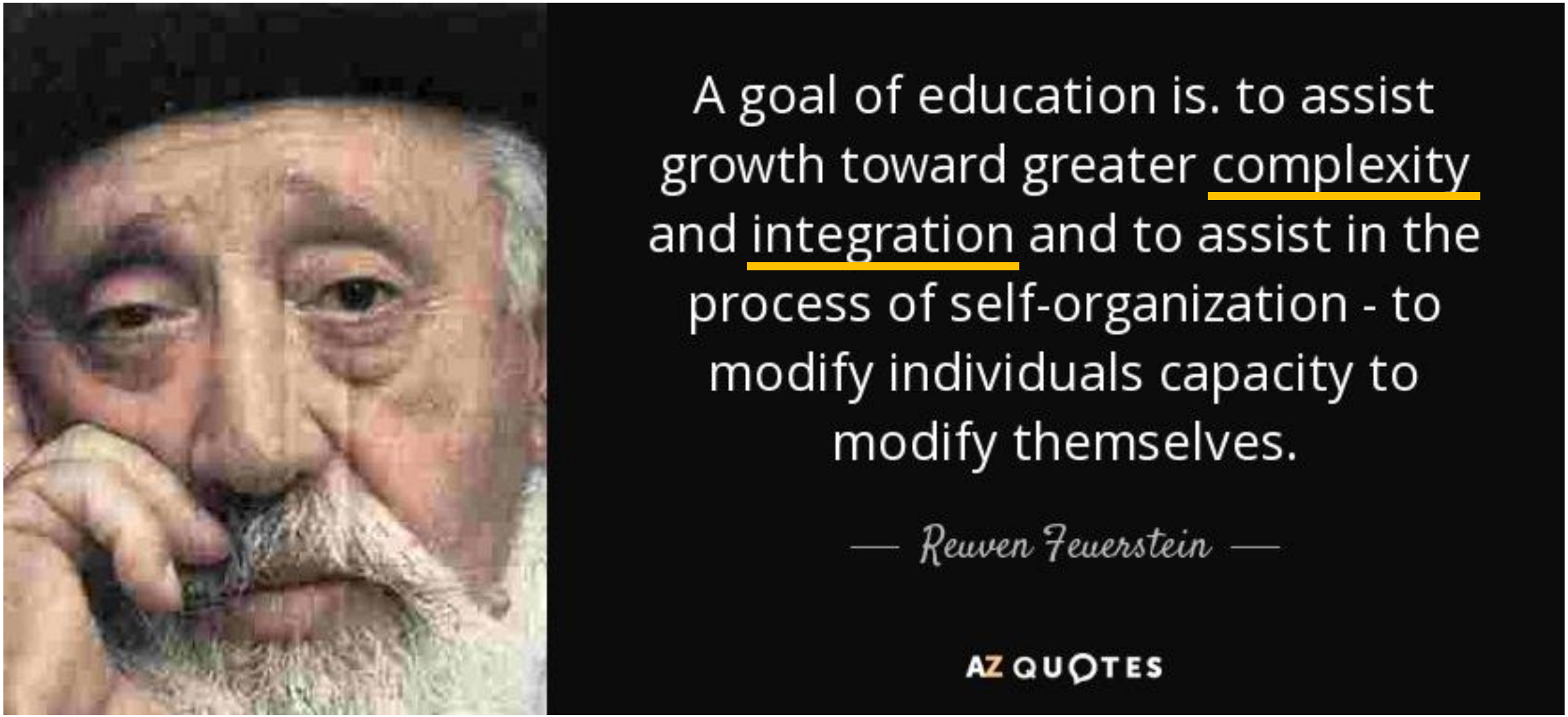
Air Domain Study (ADS)

- *SIMUA*
- *VD*

Short Projects with Companies and other Organizations

Model Based Mission Engineering (MBME)

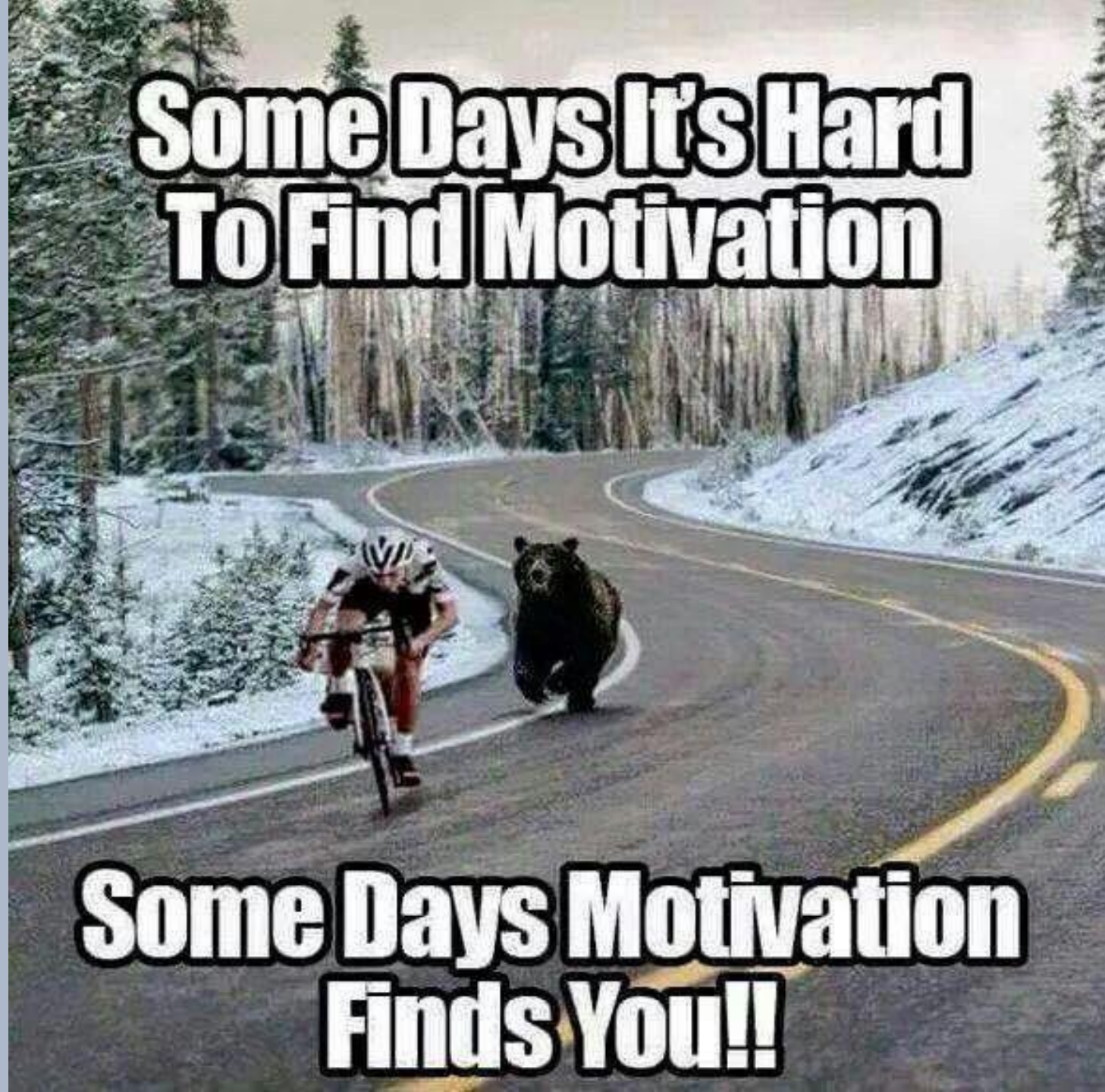
Multi-Domain Research and Demonstration Arena (System of Systems)



#escolasempartido

https://www.usatoday.com/story/life/music/2013/03/18/the-who-lyric-culture-clothing-brand/1993809/

Motivations



Model-Based Systems Engineering (MBSE) **replaces traditional document-heavy approaches with coherent models that serve as the authoritative source of truth** throughout the system life cycle.

These models help engineers reason about requirements, functions, structure, behavior, and constraints—enabling better alignment across teams and disciplines.

This course introduces MBSE as both a way of thinking and a set of practices.

We will use two major modeling languages:

- **OPM (Object-Process Methodology):** Based on a minimal, yet expressive syntax, OPM provides an integrated view of structure and behavior in a single model. It aligns well with early-stage conceptual design and supports systems thinking with strong philosophical roots.
- **SysML (Systems Modeling Language):** A standardized extension of UML, SysML provides diagrammatic tools to rigorously define system structure, requirements, activities, interactions, and constraints—supporting downstream engineering and formal traceability.

Together, OPM and SysML offer complementary perspectives on modeling: one emphasizing conceptual simplicity and holistic thinking, the other enabling precision, analysis, and integration across engineering domains.

Learning MBSE empowers you to:

- Think and **communicate** like a systems engineer.
- Handle system complexity with **clarity and rigor**.
- Design **architectures** with traceable decisions.
- Engage with modern digital engineering practices including **simulation, digital twins, and automated verification**.
- Align with leading standards: INCOSE SE Handbook, NASA SE Handbook, and ISO/IEC/IEEE 15288.

This is not just a skillset—it's a **mindset**.

MBSE will challenge how you think about systems, how you frame problems, and how you collaborate to build the engineered world of tomorrow.

Course Structure

Ementa atualizada

- Requisito: não há.
- Horas Semanais: 3-0-0-3.
- Ementa:
  - Conceitos básicos e princípios do pensamento sistêmico e da Engenharia de Sistemas. Frameworks e stakeholders. Tipos de arquiteturas, funções e análise da coesão e acoplamento. Ciclo de vida e CONOPs. Requisitos. Modelagem da estrutura e comportamento dos sistemas. Análise de contexto. Intervenção sistêmica. Exploração de alternativas. Arquitetura conceitual e desdobramento. Processo de Verificação e Validação. Arquitetura Concreta e Carta Morfológica. Desdobramento para especialidades.
- Bibliografia:
  - SEBoK Editorial Board, 2022, The Guide to the Systems Engineering Body of Knowledge (SEBoK), v. 2.7, R.J. Cloutier (Editor in Chief).
  - CRAWLEY, E., CAMERON, B., SELVA, D. System Architecture – Strategy and Product Development for Complex Systems. England. Pearson. 2016. ISBN 1-292-11084-8.
  - VOIRIN, J.L. Model-based System and Architecture Engineering with the Arcadia Method. Elsevier, 2017. ISBN 978-0-0810-1794-4.

Objetivos de Aprendizagem

- OA-P - Ser capaz de **aplicar** modelos para formalizar o pensamento sistêmico como ferramenta de engenharia para o desenvolvimento de sistemas
  - OA-1 - Ser capaz de **estruturar** o desenvolvimento de sistemas utilizando Engenharia de Sistemas baseada em Modelos.
  - OA-2 - Ser capaz de **identificar** a necessidade do uso de modelos.
  - OA-3 - Ser capaz de **identificar** as limitações e benefícios da aplicação de modelos

Languages/Methodologies

- SysML
  - Apply the Arcadia Methodology
  - non-registered – use trial
  - Students using @ga, **I'll provide a VPN to access ITA's license**

- OPM
  - Web (Proprietary but "free" for educational use)
  - https://www.opcloud.tech – non-registered
  - https://opcloud.systems – Students using @ga

1- UML 2 diagramming, OO software modeling, Source code engineering Tool MagicDraw UML from No Magic https://www.magicdraw.com/main.php?ts=download&cmd_show_mirrors=8731&menu=download_cameo_systems_modeler&c=a62cfa6271bd46bf5452e1480138f711&pr=8013&NMSESSID=9f3d0fe455b0b1dd17b3d81f94244dcc&product_version=2021x&product_edition=Cameo+Systems+Modeler%7CEnterprise&group=39

2- Fazer cadastro
3 - Selecionar Cameo Systems Modeler no menu à esquerda
4 - versão 2021x LTR / Edição Enterprise
5 - Baixar a versão (No Install)

References

[1] INCOSE. INCOSE Systems Engineering Handbook. John Wiley & Sons, 2023.

[2] ISO/IEC/IEEE, 15288-2023 - ISO/IEC/IEEE International Standard - Systems and Software Engineering--System Life Cycle Processes, 2023.

[3] SEBoK Editorial Board, The Guide to the Systems Engineering Body of Knowledge (SEBoK). Available at: https://sebokwiki.org

[4] Kossiakoff, Alexander, Steven M. Biemer, Samuel J. Seymour, and David A. Flanigan. Systems Engineering Principles and Practice. John Wiley & Sons, 2020.

[5] Voirin, Jean-Luc. Model-Based System and Architecture Engineering with the Arcadia Method. Elsevier, 2017.

[6] Dori, Dov. Model-Based Systems Engineering with OPM and SysML. New York: Springer. ISBN 978-1-4939-3294-8. 2016.

[7] CRAWLEY, E., CAMERON, B., SELVA, D. System Architecture – Strategy and Product Development for Complex Systems. England. Pearson. 2016. ISBN 1-292-11084-8.

[8] Friedenthal, Sanford, Alan Moore, and Rick Steiner. A Practical Guide to SysML. Elsevier, 2011.

[9] OMG, SysML V2: The Next Generation Systems Modeling Language! Available at https://www.omg.org/sysml/sysmlv2/

WEEK	CLASS ACTIVITY	REF	INDIVIDUAL	W	GROUP	W
1 28/Jul	Course Structure and Initial Definitions Systems Engineering Review	[1] [2] [3] [4]	IA-01 - Reading and Conceptual Questions (10)	10%		0%
2 04/Aug	Classical Systems Engineering Diagrams (IDEF-0/N2/eFFBD/DFD)	[4] *papers	IA-02	0%	GA-02 - Prepare a representation of your system using classical Diagrams	50%
3 11/Aug	Transition from Legacy to MBSE MBSE Methodologies MBSE Languages	[5] [7] *papers	IA-03 - Reading and Conceptual Questions (10)	10%		0%
4 18/Aug	OPM - Basic	[6]	IA-04 - Exercises	10%		0%
5 25/Aug	OPM - Extended	[6]	IA-05 - Exercises	10%		0%
6 01/Sep	OPM - Group Presentation		IA-06	0%	G6 - Prepare a presentation of your system using OPM	50%
7 08/Sep	SysML Introduction (bdd/ibd)	[7]	IA-07 - Exercises	10%		0%
8 15/Sep	P1 - Conceptual Questions and Case	[1] [2] [3] [4] [6]	IA-08 - Questions and a mini-case	50%	GA-08 -	
				100%		100%

WEEK	CLASS ACTIVITY	REF	INDIVIDUAL	W	GROUP	W
9 29/Sep	SysML (act/stm)	[7]	IA-09 - Exercises	10%	GA-09 -	0%
10 06/Oct	SysML (seq/uc)	[7]	IA-10 - Exercises	10%	GA-10 -	0%
11 13/Oct	Simulation on SysML		IA-11 -	0%	GA-11 -	0%
12 20/Oct 21/Oct	SysML (pkg/req)	[7]	IA-12 - Exercises	10%	GA-12 -	0%
13 27/Oct	Arcadia process applied into the SysML	[5]	IA-13 -	0%	GA-13 -	0%
14 03/Nov	Some System Analysis on SysML SysML V2 Perspectives	[8]	IA-14 -	0%	GA-14 -	0%
15 10/Nov	SysML Group Presentation Course Ending		IA-15 -	0%	GA-15 - Prepare a presentation of your system using SysML	100%
16 17/Nov	P2 - Conceptual Questions and Case	[5] [7]	IA-16 - Questions and a mini-case	70%	GA-16 -	
				100%		**100%**
EXAM 24/Nov 08/Dec	**If necessary: Writing an article (min 6pgs / max 10pgs) reporting the case of their group in the SIGE standard.**					**100%**

PROJECT BASED LEARNING

How will it be…

- Systems Engineering can be applied at any level.
- Our case study will be a Complex “Toy” System.
  - Use your imagination / we don't need to be bound by the rules of reality.
  - Each group will take part of this system.

- In order to exercise, let's assume that the strategic level has already created a high-level concept.

DISCLAIMER

The views expressed are those of the author of the material and do not reflect a policy or position of the Brazilian Air Force, Ministry of Defense, Brazilian Government or the Technological Institute of Aeronautics.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CENTRAL DE CONTEÚDO

- Esquadrilha da Fumaça - EDA
- FAB TV
- Rádio Força Aérea FM
- Imagens
- FABCAST
- Notaer
- Aerovisão
- Turma do Fabinho
- Aplicativo FAB
- Reserva Interativa
- Publicações da FAB

TODOS PELO SUL

FAB realiza maior missão de UTI Aérea no RS transportando cinco pacientes

A operação, considerada complexa, contou com o envolvimento de mais de 50 profissionais

Publicada em: 20/05/2024 10:25

Fonte: Agência Força Aérea, por Tenente Vieira
Edição: Cap Emília

https://www.fab.mil.br/noticias/mostra/42594/

lavras
que definem a maior operação de Evacuação Aeromédica (EVAM) até

C-105 (Amazonas)

https://en.wikipedia.org/wiki/Aeromedical_evacuation

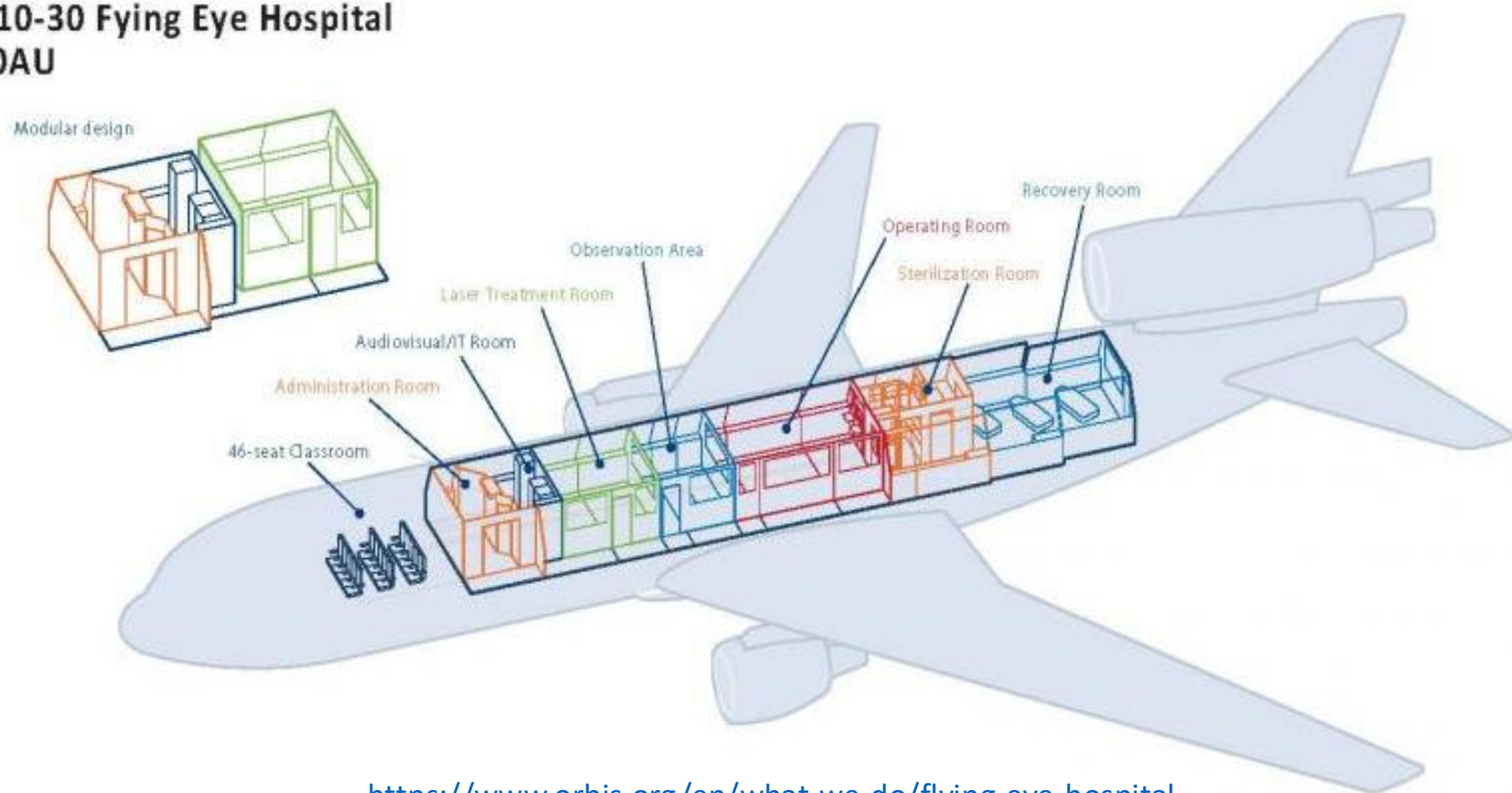
Strategic Proposal

- Requests:
  - Allow the C105 to be used as a hospital base in case of emergencies.
  - The hospital container must be all inserted into the aircraft with the functions according to the type of occurrence.
  - Must respect aircraft limits.
- Design freedoms:
  - Interaction with the aircraft (and crew), interaction with operations, interaction with patients, etc.

EXEMPLO

orbis

MD-10-30 Fying Eye Hospital
N330AU



https://www.orbis.org/en/what-we-do/flying-eye-hospital

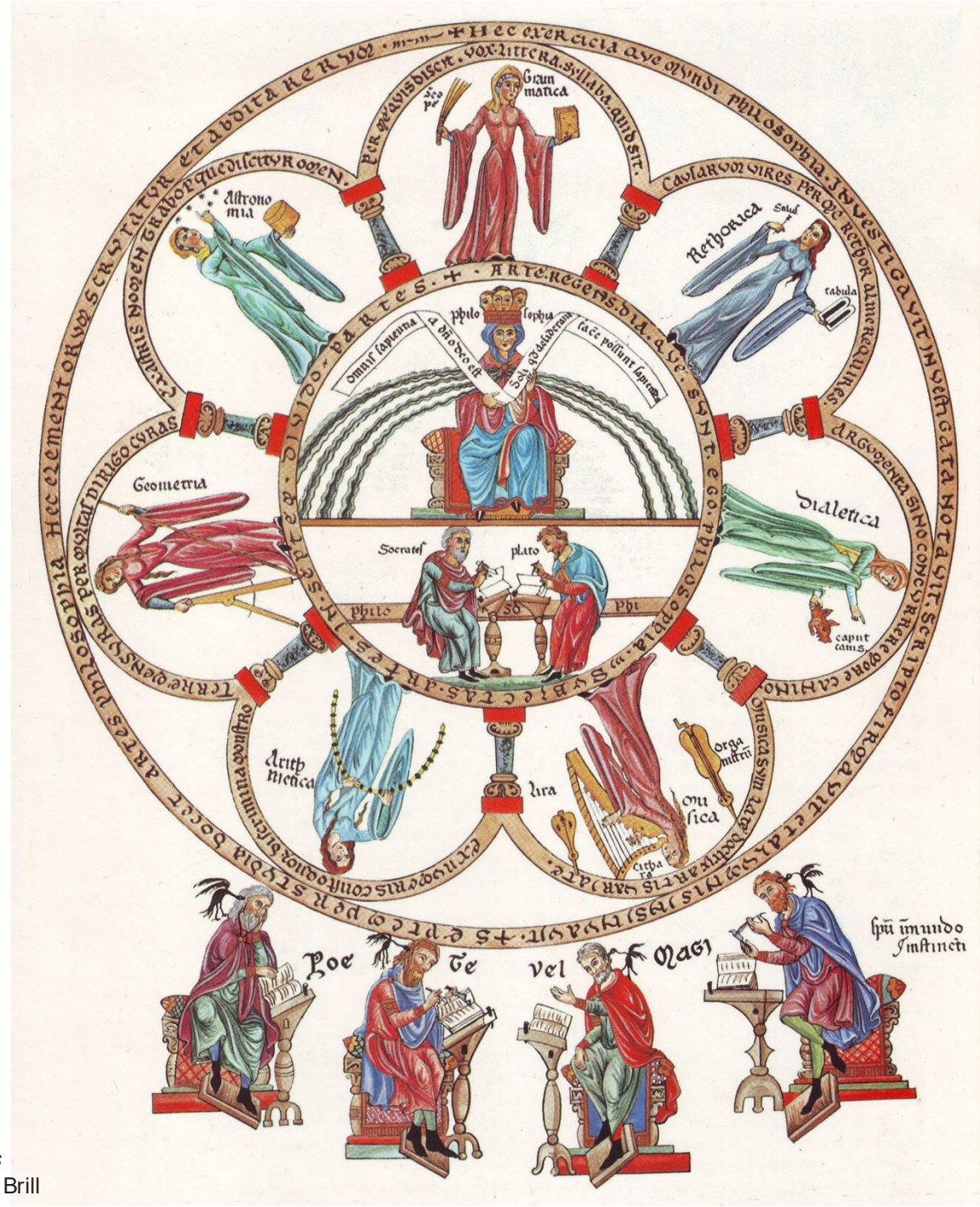
A little philosophy

Explaining the organization of the course

Hortus Deliclarium

(Garden of Delights)

- Text compiled by **Sister Herrad of Landsberg(1167).**
- It was used as a pedagogical model for young novices in convents.
- *Philosophia et septem artes liberales* (Philosophy and the seven liberal arts)



•Rosalie Green, Michael Evans, Christine Bischoff, and Michael Curschmann(ed.) (1979) *The Hortus Deliciarum of Herrad of Hohenbourg (Landsberg, 1176-96): A Reconstruction*. Warburg Institute/E.J. Brill

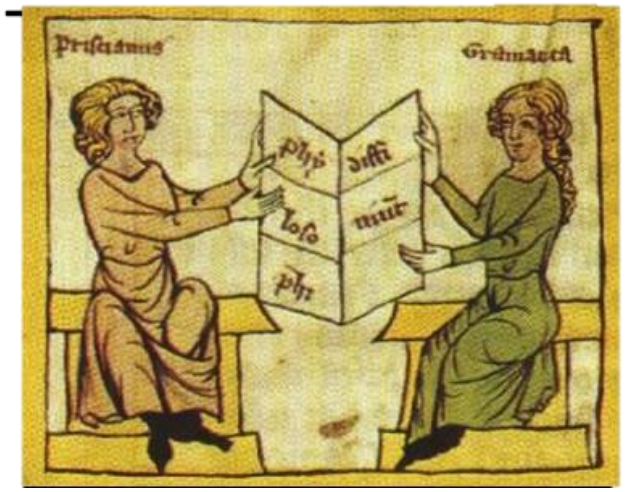
Trivium and Quadrivium

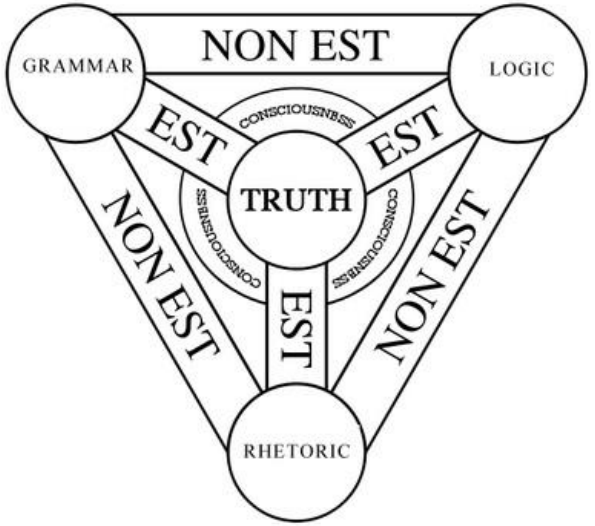
- The trivium is the part, formed by: grammar, logic and rhetoric. The Trivium is the study of the transmission of truth (language).
  - Grammar is the art of inventing symbols (signs) and their combinations
  - Logic is the art of thinking, structuring a sequence of combinations.
  - Rhetoric is the art of communication, adapting logic to circumstance.
- The quadrivium is the upper part, formed by: arithmetic, geometry, music and astronomy. The quadrivium is the study of number and its space/time relationship.
  - Arithmetic is the study of numbers.
  - Geometry is the study of spatial representation.
  - Music is the study of time.
  - Astronomy is the study of space-time.

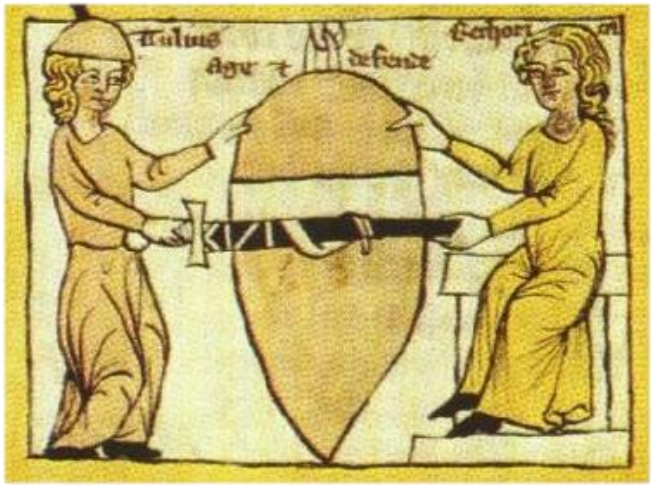
Joseph, Sister Miriam (2002). "1, The Liberal Arts". The Trivium: The Liberal Arts of Logic, Grammar, and Rhetoric. Paul Dry Books. pp. 3, 9.

Kline, Morris (1953). "The Sine of G Major". In *Mathematics in Western Culture*. Oxford University Press.

Trivium







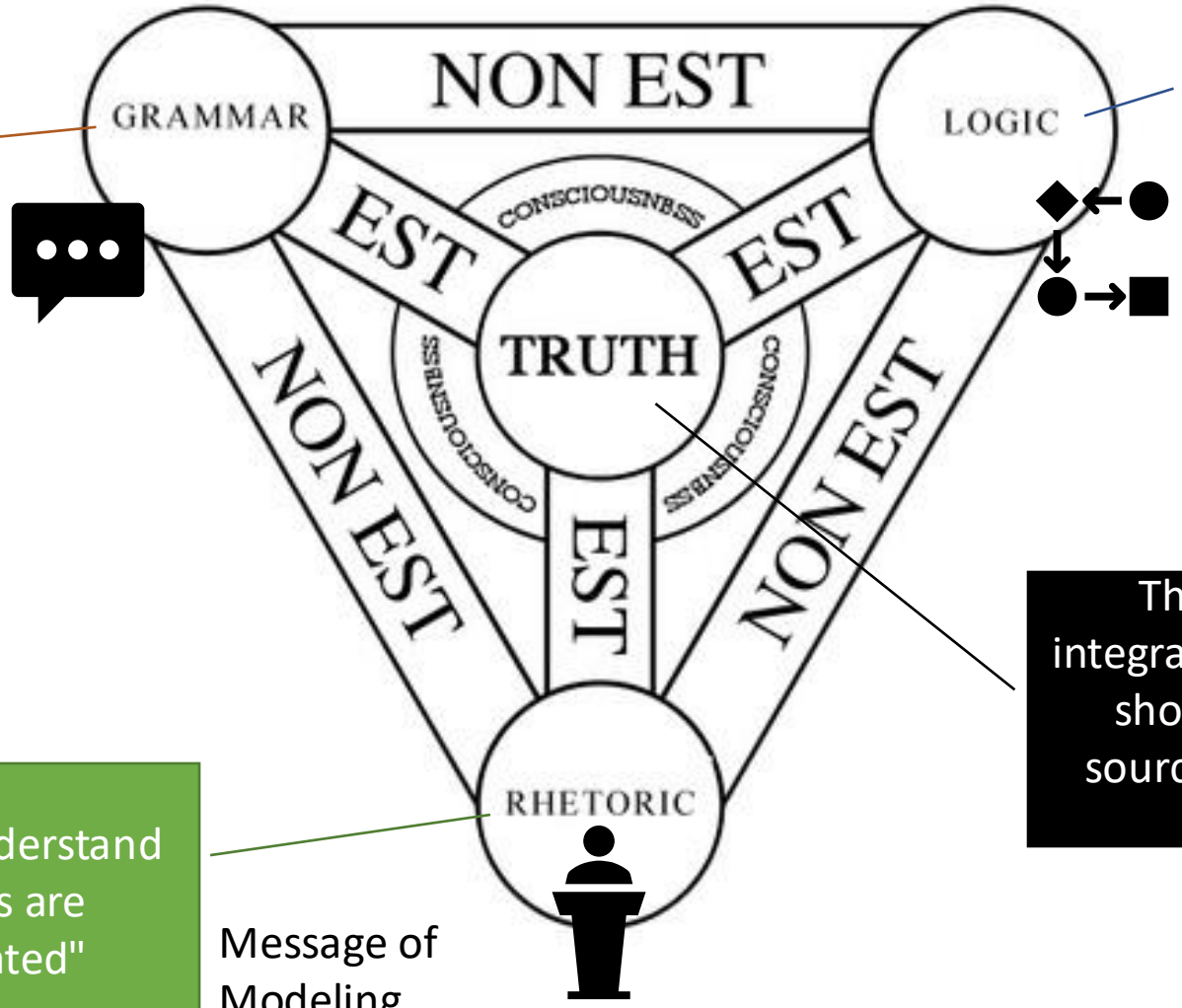
https://casadacritica.com.br/site/curso-trivium-versao-iv/

https://www.educatedclimber.com/how-to-learn-anything/

Trivium and this course

We need to understand "how things are represented"

MBSE Symbols



We need to understand "how things are known"

Interpreting the diagrams

The information integrated (in the model) should be the only source of information (truth).

We need to understand "how things are communicated"

Message of Modeling

https://augustineacademy.com.au/subjects/trivium/

Final considerations

Obs.:

- This course is always evolving – this year we will try adding a new tool.

- **Problems are expected** 🤷🏽
  - *Do not shy away from making (constructive) comments on the conduct of the course.*
  - *I will always try to keep the map of the discipline so that we know where we are in the learning process.*