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Richard Beasley, CEng, ESEP

RB Systems (richard@rbsystems.net)

Systems Lessons from the Panama Canal

1 Introduction

Contents of Presentation

1. Introduction and motivation for paper
2. Introduction to the Panama Canal
   - Geography of Central America
   - History / Timeline of Panama Canal construction
   - Key Characters
3. Systems Principles and Lessons Observed for Panama Canal Construction
4. Summary / Conclusions

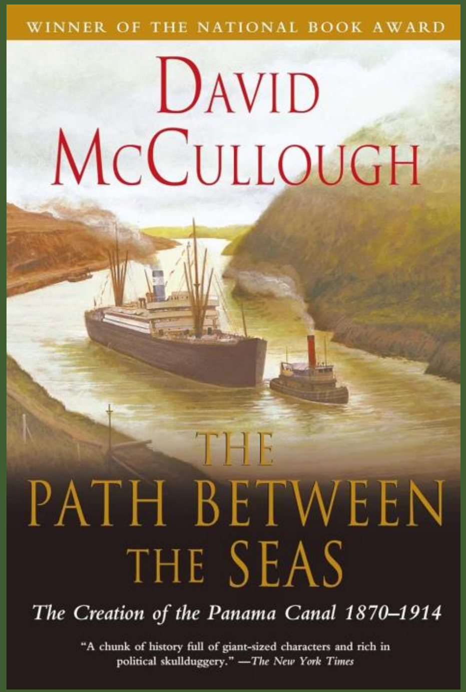
Introduction

- This presentation addresses the construction of the Panama Canal
- It extracts / observes a number of lessons regarding good and bad Systems Engineering practice
- Important to learn lessons from historic projects

Main source reference

For detail on Panama Canal history see:

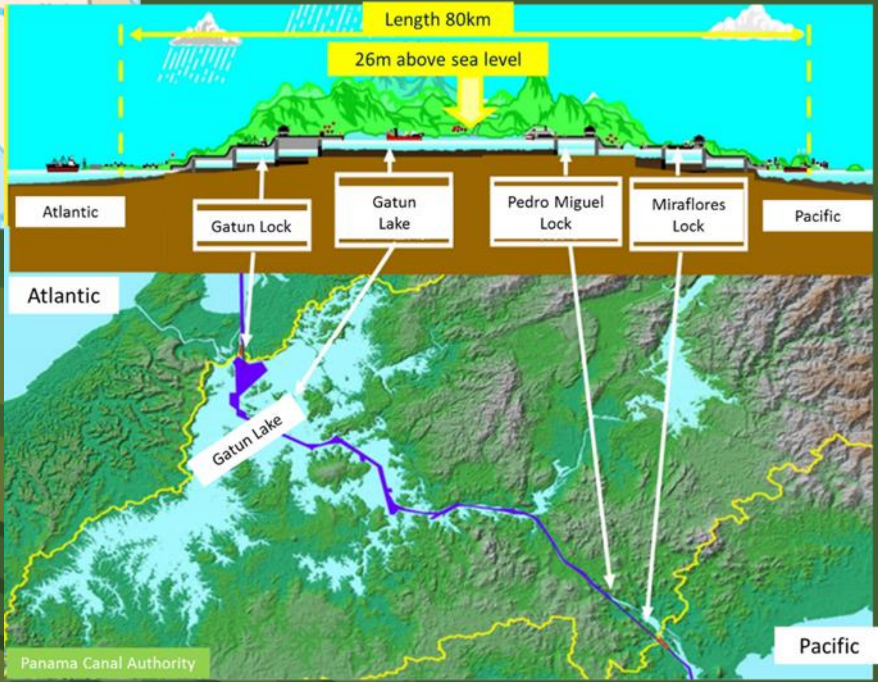
- Path Between the Seas: The Creation of the Panama Canal 1870 to 1914
- David McCullough

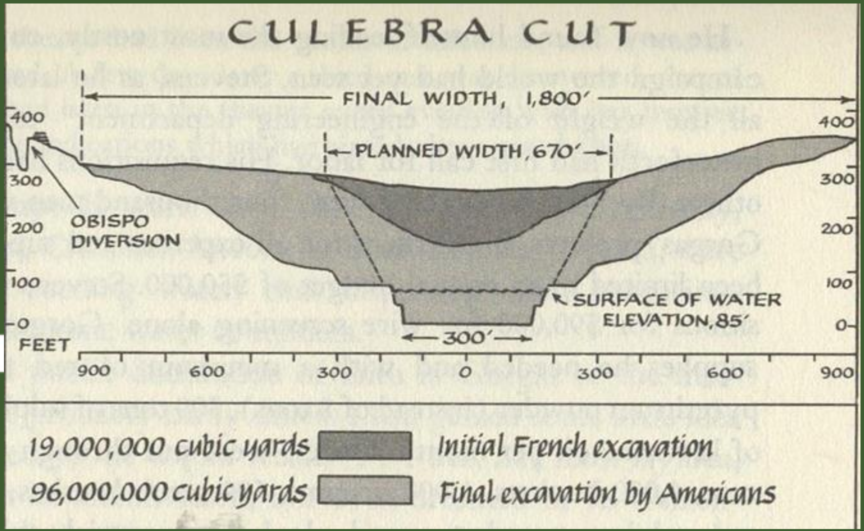


2. Introduction to the Panama Canal

- Geography of Central America
- History / Timeline of Panama Canal construction
- Key Characters

Geography (and Panama Canal Description)



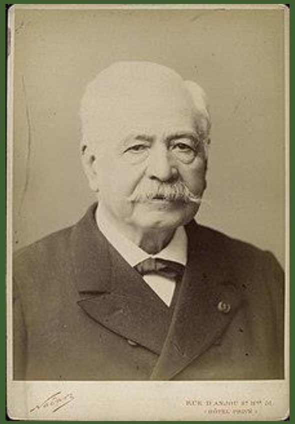


Key dates from History of Panama canal

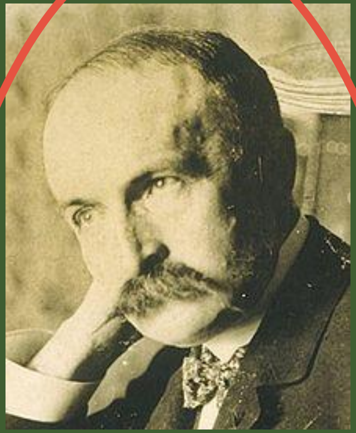
- Pre-canal
  - 1513 – First European view of Pacific Ocean from Americas and founding of town of Panama.
  - Various explorations – some very dubious (e.g. Humbolt never visited, Cullen claimed a route never >150’ elevation – never rediscovered).
  - 1855 Panama railway discovered (California gold rush). Very profitable.
- French Project
  - 1869 – Suez canal completed (de Lesseps).
  - 1880s – French company attempt to build sea level canal – disastrous financial failure, 1000s died of malaria.
- US project
  - 1897 – Discovery of cause of malaria.
  - 1899 US investigated routes. Nicaragua route favourite, unless remnants of French project sold to US.
  - 1902 – US senate passed Spooner Act authorizing Panama purchase and route.
  - 1903 – Revolution separating Panama, after Columbia didn’t ratify treaty – US “gunboat diplomacy”.
  - 1904-1914 – construction of canal by US – based on significant preparation (infrastructure and malaria control).
  - 1914 First ship transit the canal.

Key Panama Characters (dramatis personae)

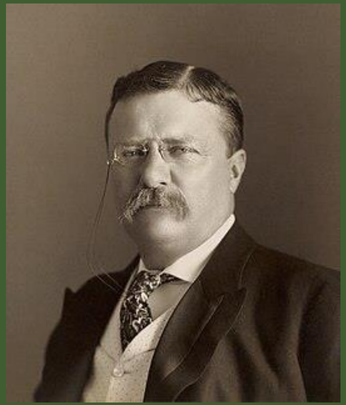
Vasco Nunez de Balboa
From - Vasco Núñez de Balboa - WikipediHa



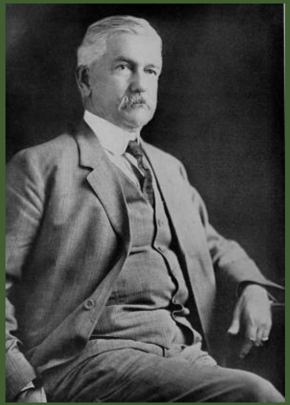
Ferdinand de Lesseps
From - Ferdinand de Lesseps - Wikipedia



Phillipe-Jean Bunau-Varilla
From Philippe Bunau-Varilla - Wikipedia



Theodore Roosevelt
From Theodore Roosevelt - Wikipedia



William Gorgas
From Theodore Roosevelt - Wikipedia

John Wallace
Chief Engineer 1904-5
From John Findley Wallace - Wikipedia

John Stevens
Chief Engineer 1905-7
From John Frank Stevens - Wikipedia

George Goethals
Chief Engineer 1907-14 and 1st Governor Panama Canal Zone
From George Washington Goethals - Wikipedia

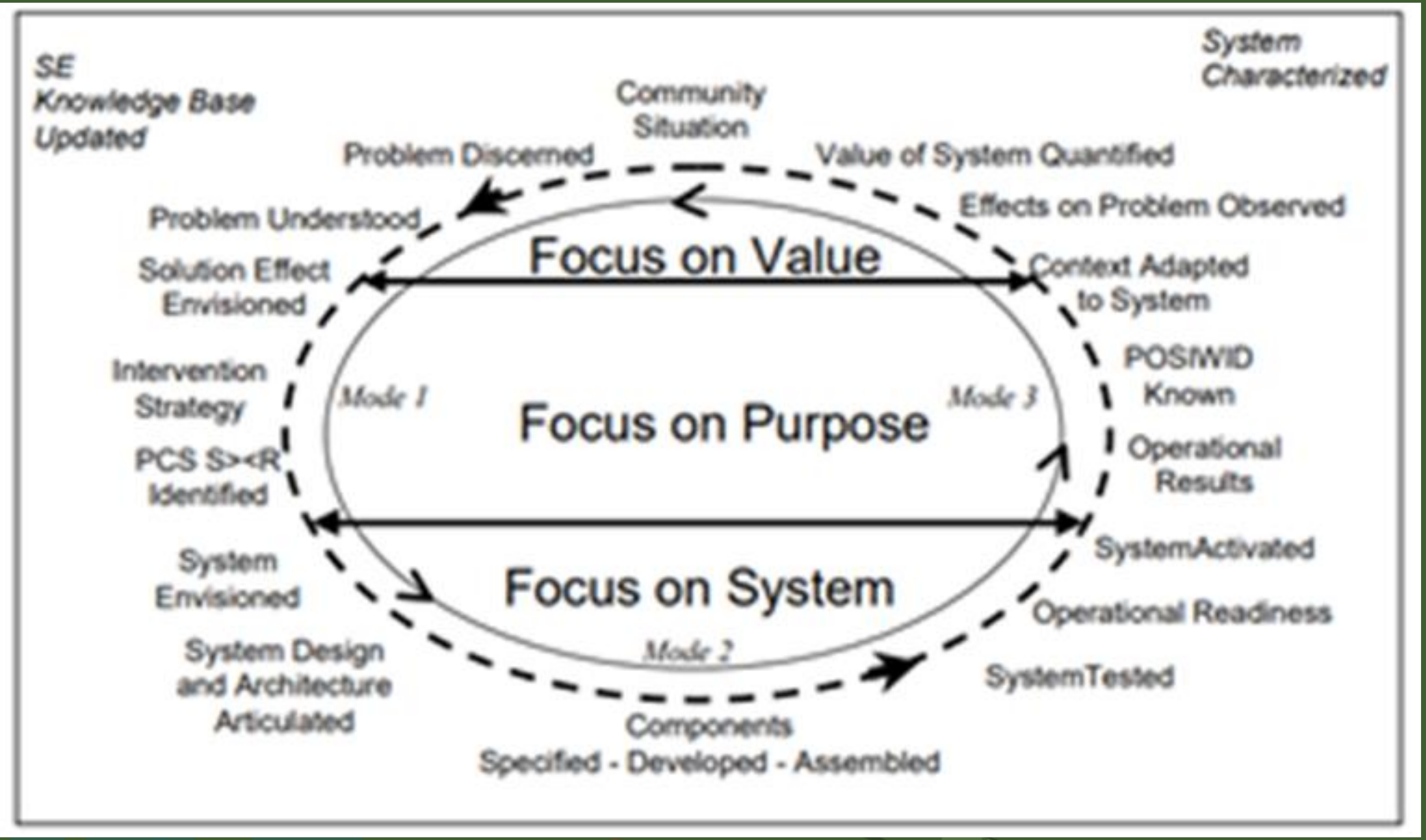
My favorites!

3. Systems principles and lessons observed from Panama Canal Construction

- Every System has a Purpose
- Every System is Influenced by / Influences its Environment
- Every System is Part of a Larger System
- Every System has Emergence
- Every Systems Needs Realization Systems To Bring it into Being
- Systems Creation Needs Focus on More Than Technical Solution
- Systems Development Projects Need Decisions and Leaders
- Every System Has a Lifecycle

These lessons are not independent

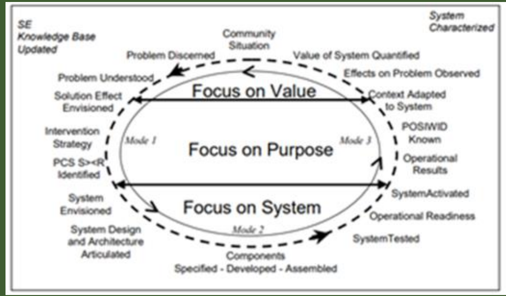
Every System Has a Purpose



- Model is Jack Ring's Value Cycle

Ring, J, 1998, Value-seeking approach to the engineering of systems, Proceedings of the IEEE International Conference on Systems, Man and Cybernetics 3 (3), 2704-2708

<u>Every System Has a Purpose (cont)</u>



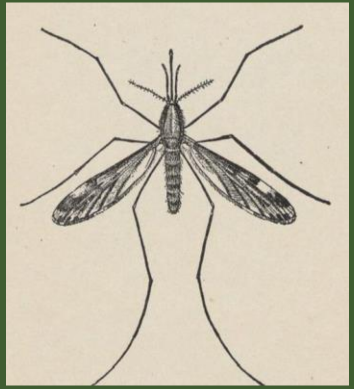
- French and USA looked to produce a canal
- Value was different
  - French – - commercial venture – generate money for investors
  - USA – strategic – allow US Navy to move between two oceans easily
- The purpose was more than just a canal – the size of endeavor meant the purpose included **<u>developing ability to build canal</u>**
- POSIWID (Purpose of System is What It Does) (Beer, 2001) doesn't hold – French project failed, USA succeeded. Why?
  - Another idea from Beer – Viable System Model –
    - French had misunderstanding of environment, fixed solution, and no communication within enterprise
    - US had problems – two Chief Engineers quit due frustrated by organization bureaucracy (control by committee from Washington)
- US project success ultimately down to sticking with value – and recognizing what was important
  - Preparation to control hygiene (Gorgas) and the construction realization system (Stevens)
  - Willingness to adapt solution (move to locks) and organization in order to create a working canal

<u>Always "big picture" – ask WHY you are doing it, not just WHAT you are doing</u>

Every System is Influenced by / Influences its Environment

- Essential to understand the environment the System of Interest fits in
- Environment was a "stakeholder" (a source of constraints) for the Panama canal
  1. Climate / geography = stakeholder you can't negotiate with!
     - French decision made by people who mostly hadn't been to Panama
     - Recognise environment creates "needs" for engineers to convert into requirements
  2. Mosquitos as vector for Yellow fever / malaria – not known at time at French project (~22,000 deaths in French project)

- French Project not only failure in region
  – 1690s Scottish colony in nearby Darien best by fever
  – Effectively bankrupted Scotland, contributing to decision in favour of 1707 Act of Union with England



Anopheles – Malaria vector

Stegomyia – Yellow fever vector

Images from: Sarah J. Moore, "Mosquitoes, Malaria, and Cold Butter: Discourses of Hygiene and Health in the Panama Canal Zone in the Early Twentieth Century," *Panorama: Journal of the Association of Historians of American Art* 3, no. 2 (Fall 2017), https://doi.org/10.24926/24716839.1603.

Every System Is Part of a Larger System

- Prior to 1903 Panama was a part of Columbia
- To achieve US sovereign interests Roosevelt didn't want "the Bogota jack-rabbits delaying one of the future highways of civilisation"
  - Encourage by Bunau-Varilla "influencing"
- "Encouraged" revolution in Panama – and USS Nashville ("to protect peace") prevented any movement of armed force (if Columbian forces had arrived "Republic of Panama wouldn't have lasted a week"!)
- Not sure gunboat diplomacy a valid tool for 21st century Systems Engineering!

Image from Big Blue 1840-1940: Panama

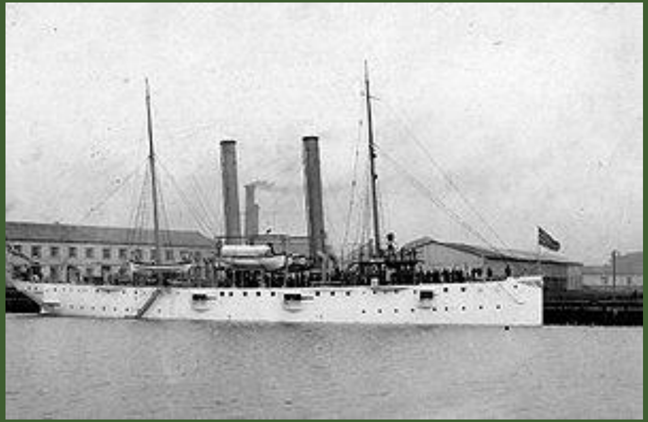


Image from USS Nashville (PG-7) - Wikipedia

See also issues about diseases as a part of environment

Every System Has Emergence

Malaria

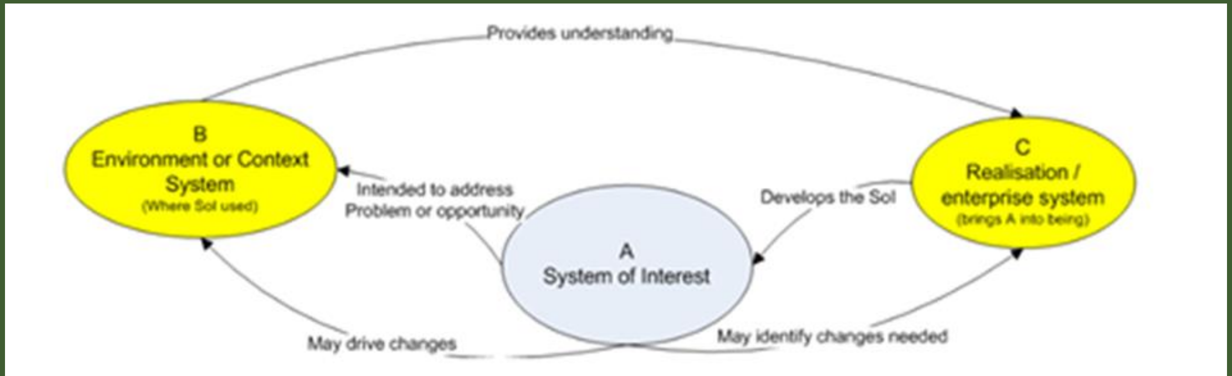
- In 1880s vector of Malaria and Yellow fever unknown
- French wanted “pleasant” surroundings – planted trees etc.
- Pots of water used to protect from ants
- These pots an ideal location for mosquitos to breed
- Gorgas (in 1900s) wrote if the French had been trying to propagate Malaria they couldn’t have done it better
- Between 1881-89 22,000 deaths due to malaria / yellow fever (for reference work force in 1888 was 40,000)

French “money pit”

- French company budget based on assumption of “Suez-style” solution
- By 1885 clear the proposed solution could not be built (within budget)
- Several increasingly desperate attempts to raise more capital
  - Including a share lottery!
- In 1889 company went bankrupt
- Lesseps and others (including Gustave Eiffel) given long jail sentences for hiding financial reality
  - Sentences annulled due to time between crime and sentence

Image from: Sarah J. Moore, “Mosquitoes, Malaria, and Cold Butter: Discourses of Hygiene and Health in the Panama Canal Zone in the Early Twentieth Century,” *Panorama: Journal of the Association of Historians of American Art* 3, no. 2 (Fall 2017), https://doi.org/10.24926/24716839.1603.

Every System Needs Realization Systems to Bring it into Being



From Beasley, R., and Pickard, A., 2020 The Capability to Engineer Systems is a System Itself, INCOSE IS 2020.

A simplification of James Martin's 7 samurai - solution

- Needs to understand environment
- Have right realization systems to produce / support it

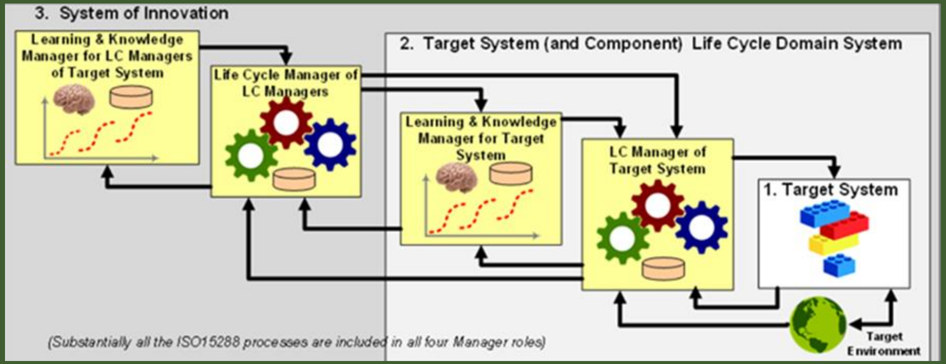
1. **Sanitation**

- 19th / early 20th century Panama not a healthy place
- Means of transmission (mosquitos) only discovered in 1897.
- Gorgas (experience in controlling Yellow Fever in Cuba in 1901) employed as Sanitation officer.
- He, persistently and against much opposition, implemented a far-reaching sanitary program.

2. **Logistics**

- Stevens (2nd US Chief Engineer) concentrated on infrastructure needed to allow canal to be dug (rather than trying to "make the dirt fly" with what there was already available).
- Said "Digging is least of all".
- Built railroad for logistics (equipment, workers and supplies in, earth out), supported Gorgas sanitation, and warehouses, accommodation.
- In 1906 12,000 of 24,000 putting up buildings.

Every System Needs Focus on more than Technical solution



From Schindel, W., and Dove, R., 2016 Introduction to the Agile Systems Engienering Life Cycle MBSE Pattern, INOCSE IS 2016

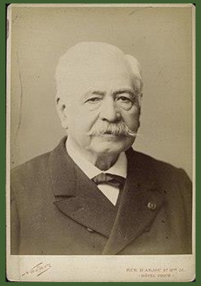
Another – important 3 system model

Need to understand the technology and organisation needed to deliver canal

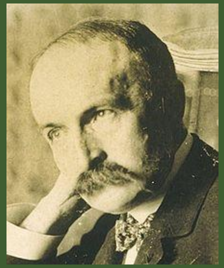
1. In time between French and US projects canal technology hurdles (dams and digging) overcome, and scientific understanding of causes of malaria achieved
2. Project governance improved
   - Initial over-bureaucratic 7 man pollical panel in Washington DC
     - Single handcart required 6 signatures to allow procurement
   - Improved to 3 man panel – 2 in Panama (Governor and Chief Engineer) and one in Washington
3. Organization changed to suit
   – Stevens focused on disciplines in the “preparatory” phase
   – Goethals re-organised into 3 areas (Atlantic, Pacific and Central) for the “build” phase
   – Each totally appropriate to the work needed at time

System Development Projects Need Decisions and Leaders

1. Leadership a key part of Systems Engineering
2. De Lesseps was a dominant leader:
   - Proven skills on Suez canal
   - Convinced that (lockless) solution would work in Panama
   - Dominated conference to choose route and style – Panama and lockless chose –
     - 136 delegates – of 74 to vote for solution only 19 engineers and only one had ever been to Panama
3. US Project initially very in favor of Nicaragua route
   - This despite Panama "technically" very superior
   - Decision makers were political (not technical). Bunau-Varilla (who did have commercial interest in Panama route due to shares in remnant of French project) used communication and influencing skills
     - Extremely simple diagrams (Child primer level) to sell pro-Panama technical argument to senators



Ferdinand de Lesseps
From - Ferdinand de Lesseps - Wikipedia



Phillipe-Jean Bunau-Varilla
From Philippe Bunau-Varilla - Wikipedia


10 NICARAGUA 10
CORREOS
CORREOS
10 CENTAVOS 10
AMERICAN BANK NOTE CO. N.Y.

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     - Extremely simple diagrams (Child primer level) to sell pro-Panama technical argument to senators
     - Exploited concerns over seismic activity in Nicaragua. Nicaragua route supporters case not helped by stamp at the time showing a smoking volcano as background to celebration of new railroad
4. Systems Engineering skills not enough – need influence and communication skills to be effective

From Bickel, J., 2020, A Stamp that Changed History: How the Panama Canal was Almost the Nicaragua Canal, blog entry on Smithsonian National Postal Museum website

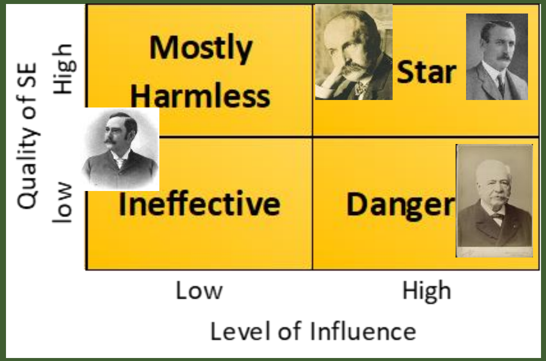
System Development Projects Need Decisions and Leaders (cont)

1. Leadership comparisons

- Lesseps selected solution (based on his previous success not information regarding Panama Canal
  - High level of influence (based on Suez reputation), but inappropriate engineering
- Bunau-Varilla had strong interest in Panama route, used sound engineering proposal for canal coming from ruins of Lesseps, and strong influencing skills to get US senate / Roosevelt to commit to Panama route

2. SE Quality vs influence

- This matches the chart from Kemp comparing level of Systems Engineering quality and influence in an individual – emphasising the importance of influence



From Kemp & O'Neil, 2019, *12 Principles for SE leaders*, INCOSE International Symposium 2019

3. Leadership commitment

US project had 3 Chief Engineers – with various effectiveness and commitment

- John Wallace – didn't like bureaucracy (control from Washington), weather and health – quit in 1905
- John Stevens – created realization system (based on railway experience) – bored by idea of "digging a ditch"
- George Geothals (1907 – completion) – used Stevens' preparation to successfully complete project (early)

Last two were right leaders (right skills / focus) for the phase of the project

Every System Has a Lifecycle

Not really covered in McCullough book, but longevity of Panama canal has seen upgrades

- US design designed for future larger ships.
  - Original locks 110’ wide – largest battleship on drawing boards at time had beam of 98’, the Titanic had beam of 94’
  - Pacific side had breakwater built to protect from silt
  - Upgrades to defend canal – purchase of Virgin Islands, and aerial defence in 1940
  - 2006-2016 - $5.25bn investment in third lane of locks to allow “Panamax” ships transit, and made maintenance easier

4 Summary / Conclusions

Concluding comments

Important to learn lessons from history

Panama Canal built before Systems Engineering defined, but standard principles apply

1. You should understand context and environment into which your system fits.
2. Don't jump to system solution – and recognise a successful solution in one environment may be ruinous in a different one.
3. System development depends on Realisation systems which need to be prepared.
   – Short term progress (tons of earth dug) may not predict long term success – prepare, then exploit the preparation.
4. Leadership is vital – ability to understand, set direction and clearly communicate are vital.
5. Organization needs to be appropriate to project lifecycle phase – and so change during lifecycle doesn't mean old wrong and new right – just appropriate to situation.

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www.incose.org/symp2024
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