20 years of SPDM in successful production; towards a convergence of SPDM and PIDO

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Agenda

- Introduction

- Technology landmarks over 20 years of SDM and SPDM

- Challenges and solutions

- Conclusions

Introduction

- Germany's leading companies, BMW, Audi,..
    - Invented Simulation Data Management,
    - Invented Simulation Process and Data Management
    - Use SPDM to manage all their simulations; FEA, CFD, 1D,….
    - We have 20 years experience of how to succeed with SPDM

- The **business impact** of SPDM in mainstream product development has been impressive, even **transformational** for leaders

- Simulation on a digital platform must be **the future of engineering**
    - The US DoD has now mandated Digital Engineering for all programs: managed models on a digital platform, an enduring source of truth

- But **uptake of SDM has been much lower than PDM**

- The integration of PIDO to SDM is one way to accelerate adoption

Going forward, models, CAE applications and data will be managed on a Digital Platform

- The US Department of Defense published its Digital Engineering Strategy in 2018, the DoE just launched a similar program

- Going forward, it will be **mandatory** to **manage models, applications and data** on a **Digital Platform**, an Authoritative Source of Truth

- To achieve this we need to **connect** models, applications and data to the **platform – that is called SPDM**
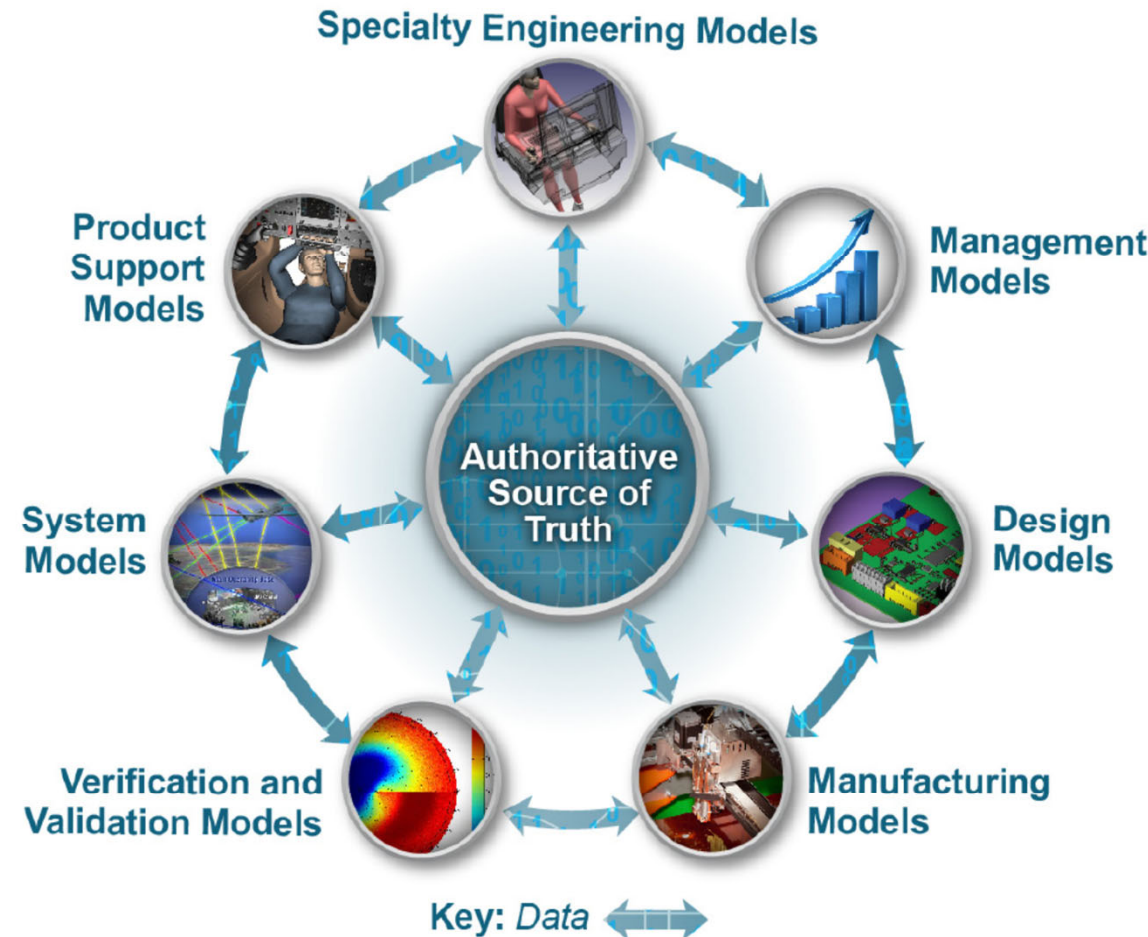
Digital Engineering Strategy

The 3 purposes of an SDM solution

- To provide an **ergonomic** working environment for simulation engineers to
  - **find** the data necessary to execute numerical simulations
  - **launch** CAE applications and **save** outputs to a structured digital repository
  - painlessly **capture metadata** and the **digital thread** to **document** their activities
  - **share** the results and conclusions of simulations with peers, managers and clients
- To provide a **secure, productive information system** to support **Digital Engineering**
  - Provide **traceability** of data and processes to assure confidence in results
  - Support **digital certification** of products
  - Protect intellectual property (**IP**)
  - To **provide productivity gains** from data management automation
- To provide **a platform for process automation** for advanced applications; PIDO, Surrogate Modelling, UQ, RD, Data Mining, Artificial Intelligence, Machine Learning, Digital Twins,...
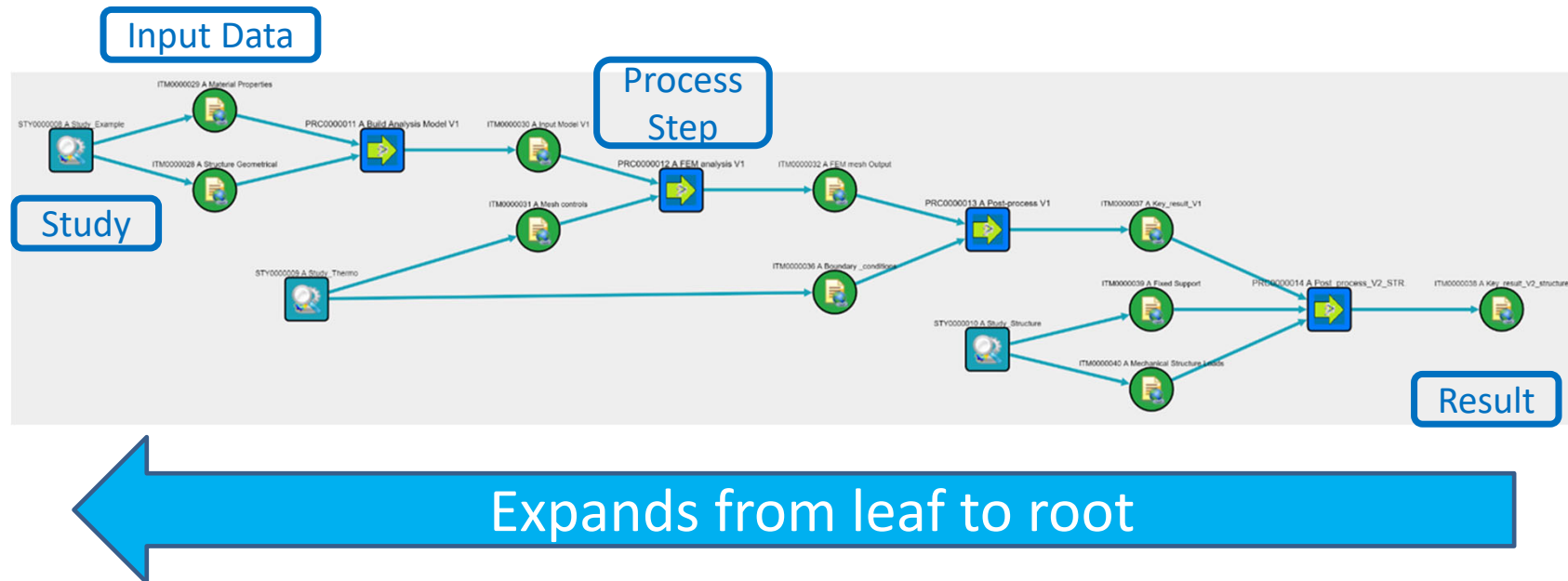
How did you get this result?

SDM uses **graph technology** to trace the **Digital Thread** from results through the process back to the inputs.

The engineer:

- can display the complete simulation process followed
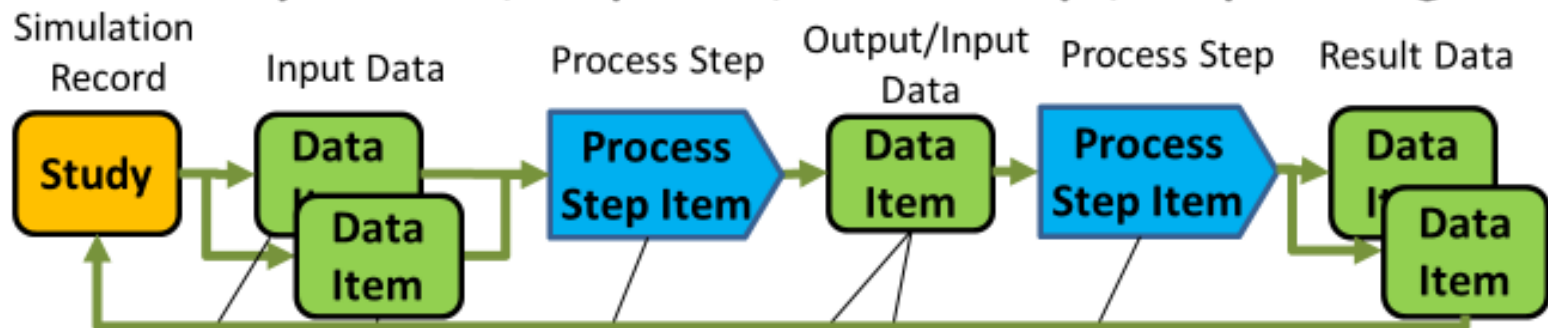- open any data or process step object with just one click
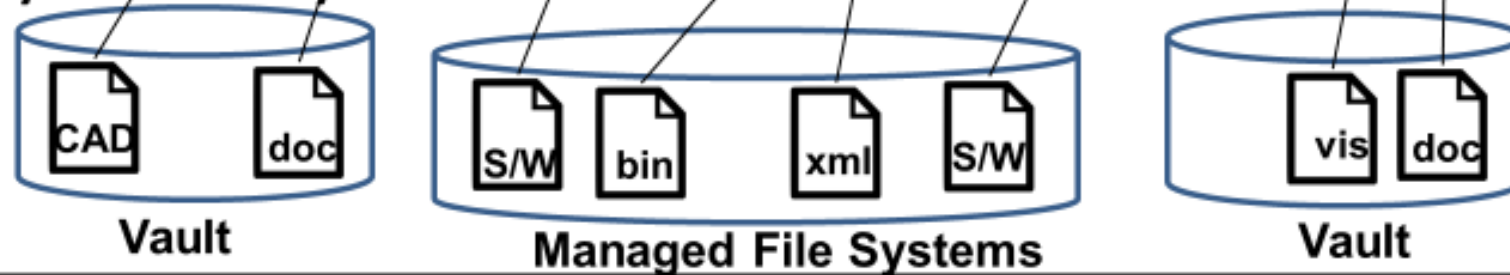
Simulation Data Management Solution

20 YEARS OF SDM AND SPDM

Milestones on the Timeline to Digital Engineering

2000   2010   2020

Standard Solutions

VDA 4967 4969

PORSCHE **SimData Manager**

Ford **Safety VDSS**

BMW **SimManager**

BOEING **Internal Loads SimManager**

BMW **Multi-body SimManager**

EMBRAER **Digital Certification SimManager**

GKN Driveline **SimManager**

Ford **Meshing Tc4Sim**

Audi

LOCKHEED MARTIN **Open SimDM**

RENAULT **SPDRM**

Aim
- High SDM capability
- Many integrations
- affordable xLM platform

Systems

Audi **SimManager™**

AIRBUS **High Lift Virtual Test SimManager™**

LoCo SimData Manager SimManager™

S **Landing Systems** Ansys **EKM**

UK Atomic Energy Authority **openSPDM/Aras**

Projects

BMW **CAE Bench Virtual Insight**

JET

AIRBUS **AeroCity**

Sandia National Laboratories **In-house on MatrixOne**

faurecia **Seating In-house**

AIRBUS **Powerplant Int Virtual Test Tc4Sim**

S **CERBER openSPDM/Aras**

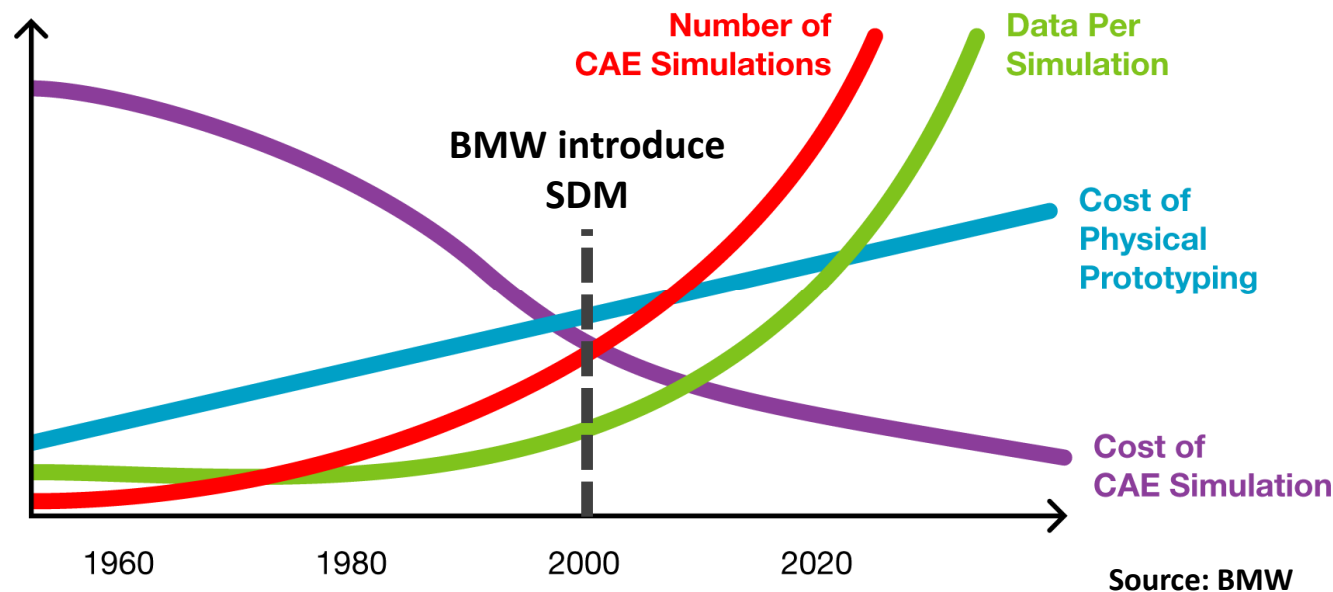TOYOTA MOTOR EUROPE **Aras SE**

BMW & SGI invented SDM to **assure quality** as simulation replaced prototype testing

Expanding Capacity, Managing Process & Data

⇧ # of CAE Simulations
⇧ Complexity of Simulations
⇧ Data per Simulation

+

Nearshore/Offshore Development & Integration

Number of CAE Simulations

Data Per Simulation

BMW introduce SDM

Cost of Physical Prototyping

Cost of CAE Simulation

1960   1980   2000   2020

Source: BMW

Driving Demand for Analyst Productivity

and increased engineering throughput: reducing time to perform a safety simulation

2002: 2.5 days per simulation

2018 ten simulations per day

fully documented and traceable

TABLE 6 - 1

Learning by Crash Simulation and Prototype Testing*

Numbers are estimates from a project at BMW and are subject to change. Prior to starting simulation, there is a one-time fixed investment necessary to build a basic model that can be reused with modifications during the following experimentation cycles. Prototype-build cost and time are naturally a function of the magnitude and number of modifications, but even modest changes can drive up cost and time substantially. Examples of such cost drivers are tooling, material, and labor.

Experimentation Step	Simulation Only (per iteration)	Physical Prototype Only (per iteration)
1. Design	*Technical Meeting* • less than 0.5 days	*Planning and Piece Part Design* • more than 2 weeks (involves many meetings)
2. Build	*Data Preparation and Meshing* • small change: less than 0.5 days • significant change: 1 week • entire automobile: 6 weeks	*Design and Construction* • using existing model: 3 months (at $150,000 per prototype) • new model: more than 6 months (at up to $500,000 per prototype)
3. Run	*Crash Simulation* • 1 day (varies with computer hardware) at $250 per day	*Crash Physical Prototype* • 1 week (includes preparation of test area)
4. Analyze	*Post-Processing and Analysis* • less than 0.5 days	*Data Preparation and Analysis* • 1 day (crash sensor data only) • 1 to 3 weeks (data, crash films, and analysis of physical parts)
Total approximate time	2.5 days to 6.3 weeks	3.8 months to more than 7 months
Typical cost (includes effort)	Less than $5,000	More than $250,000

*The cost and times are based on data collected in 1997 and have experienced some changes in favor of simulation. For a more detailed explanation of the methods used to collect the data, see Thomke (1998b).

PROCESS INTEGRATION IN SPDM AT BMW GROUP.
USAGE OF SPDM AT BMW GROUP: CAE-BENCH.

ObjectType	Count	Size
Submodel	> 500,000	> 90 TB
Inputdeck	> 1,300,000	> 350 TB
Result	> 1,000,000	> 500 TB
KeyResult	> 60,000,000	> 40 TB
Report	> 110,000	
	Over all	> 970 TB

up to 5.000 simulations per day

> 3.4 million simulation data sets

up to 500 concurrent users

7 x 24 operating

Process Integration in SPDM at BMW Group. I November 28, 2018

The Engineering Revolution @ BMW through SPDM

BMW Product Line in 2000
3 models, 3 virtual prototypes
Simulation replaces test

BMW Product Line in 2020
78 models,
50+ virtual vehicles
being simulated

Airbus in-house SDM for CFD, platform for PIDO

Fig. 2

Airbus Aerodynamic Framework : AeroCity; T.Chevalier; Airbus;   International Conference on Trends in Product Life Cycle Modelling, Simulation and Synthesis PLMSS-2006.
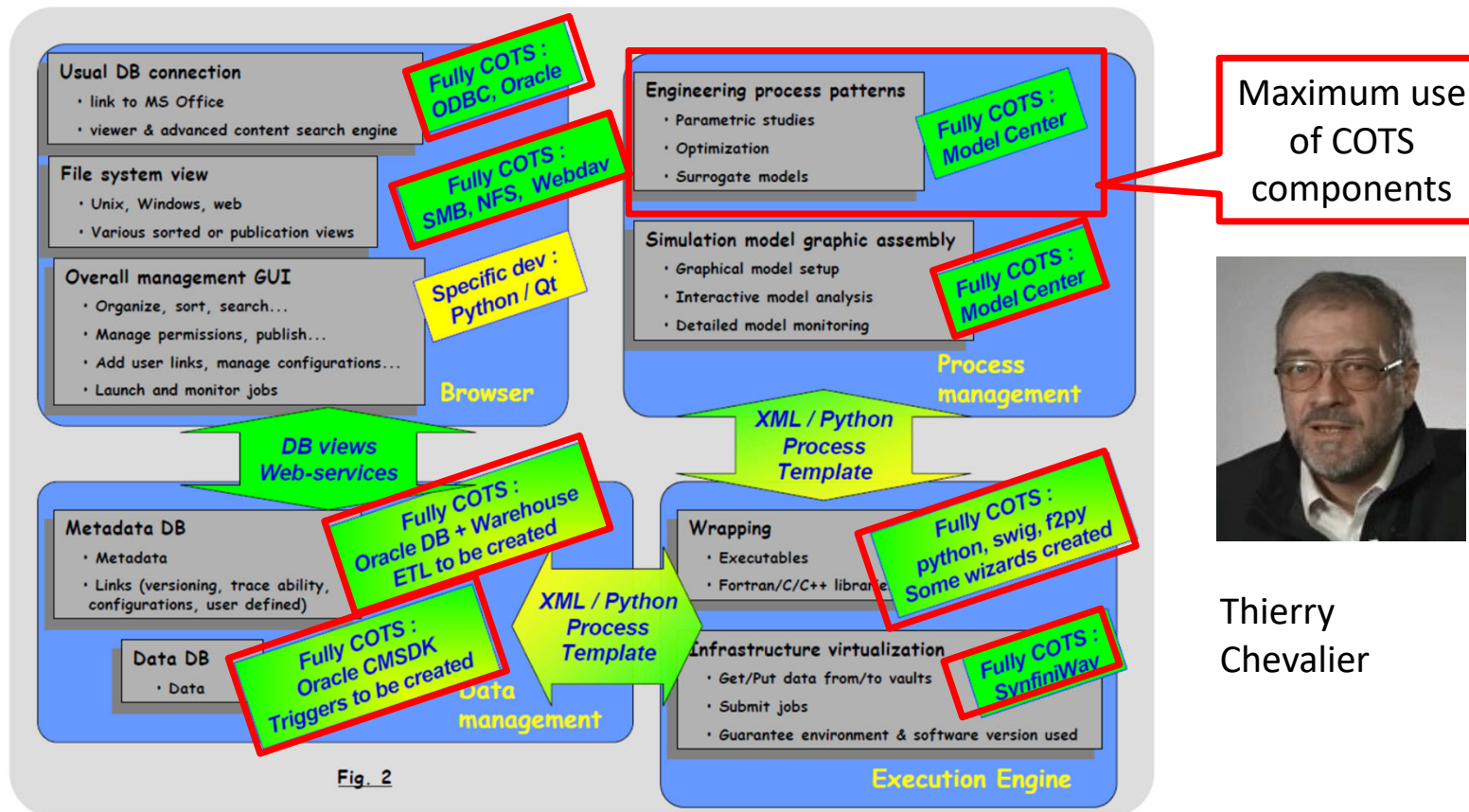
Thierry Chevalier

Sandia Labs: SAW Workbench underpinned by SDM

Support the Design-To-Analysis process, capturing data in context

Revolution in Simulation Management:
a fourth generation of openSPDM has arrived

NWC 2021
NAFEMS WORLD CONGRESS
A WORLD OF ENGINEERING SIMULATION
INCORPORATING
spdm INTERNATIONAL CONFERENCE
Simulation Process & Data Management

UK Atomic Energy Authority

Next-generation information system architecture for simulation-led engineering of a fusion reactor

Mark Norris
theSDMconsultancy

V=100,000m/s

NAFEMS World Congress 2021

spdm 2021

spdm
Evaluating the Innovator xDM platform
SDM Components & Enablers vs SDM Best in Class

Score of capability
5=Excellent

Agile development environment enables SDM data model to be developed rapidly

Best in class SDM
Green

xDM platform
Blue

Extensive studies available on Data Models from VDA, MoSSEC,... 10's of Millions of Euros spent

xDM Platform
SPDM Datamodel
SPDM Services
SPDM Integration Framework
SPDM Web UI
Configurable SDM Apps
Agile Development Env.
SDM Solution Architects
Visionary Industrial Customers

Third Party Solutions

spdm
INTERNATIONAL CONFERENCE
Simulation Process & Data Management

CERBER
Conception et Etude de Roulement
à Billes Et à Rouleaux

CERBER, an SPDM Proof Of Concept
based on OpenSPDM
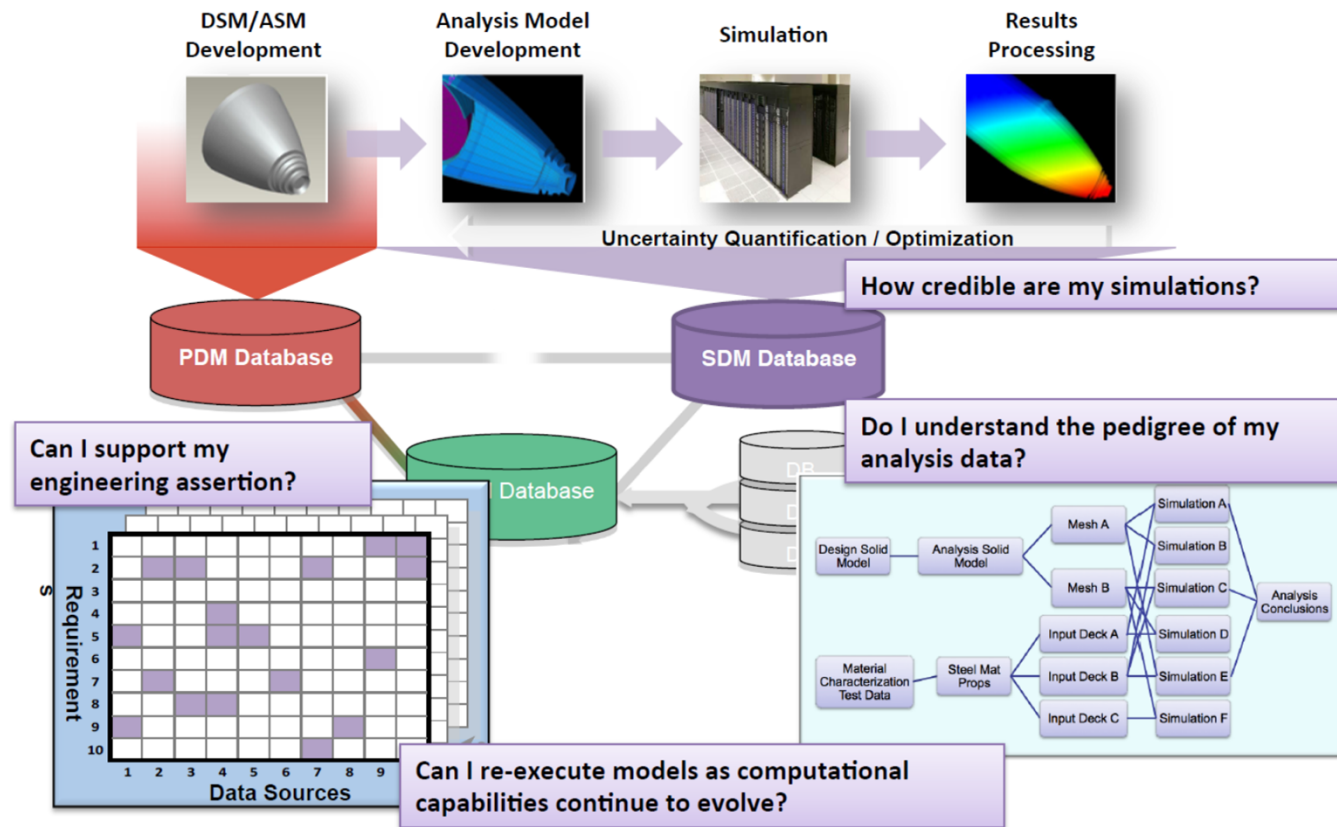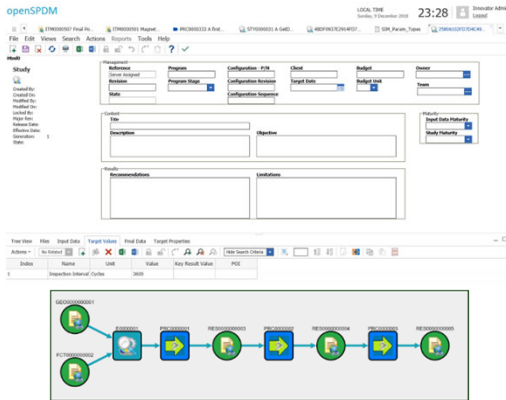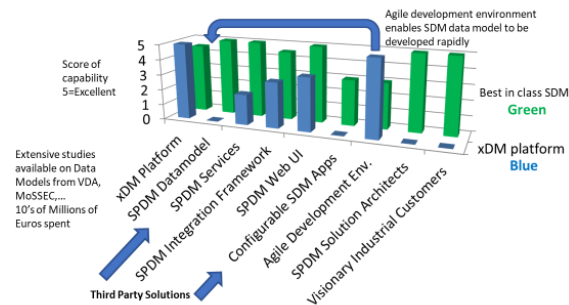Bearing design for Aircraft engines

Leroux Julien, Safran Aircraft Engines
Le Lann Cyrille, Safran Aircraft Engines
Delabrousse Gilbert, Inensia
Norris Mark, TheSDMConsultancy

4th International Conference on Simulation Process & Data Management | 17-20 June | Quebec City | Canada

spdm 2019

Impact of pilot implementation

A first step towards an ideal process, we could already appreciate merit

With digitalised process:
- Consistent communication on data requirements
- Parallelisation of preparation work
- Data checked / certified at the source, with metadata and evidence
- No more file tracking and merging
- First automated feed for mass/CoG/inertia
- Can reuse previous data and metadata
- ...

Process lead time

-28%   Reference
       New process

Manpower spending

       Reference
-41%   New process

Impact:
- **MBD engineers** free resources for technical development
- **Designers** free resources for project
- **Performance engineers** get models earlier and use with more confidence
- ...

Data from actual project for preparation and data gathering phases

TOYOTA   NAFEMS World Congress 2021

spdm 2018

European | SPDM | Conference 2018 | 28-29 November | Munich | Germany

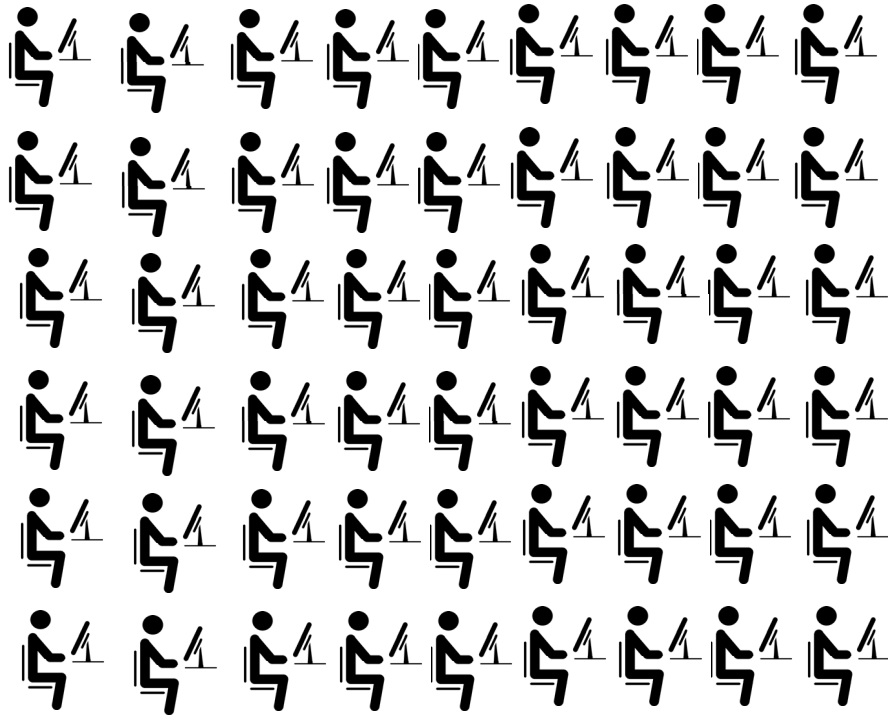Bringing Global Best Practice to Simulation Management, SDM and SPDM

DEPLOYMENT CHALLENGES AND SOLUTIONS: INTEGRATION IS THE NUMBER 1 CHALLENGE

SDM is inherently **Different** to PDM
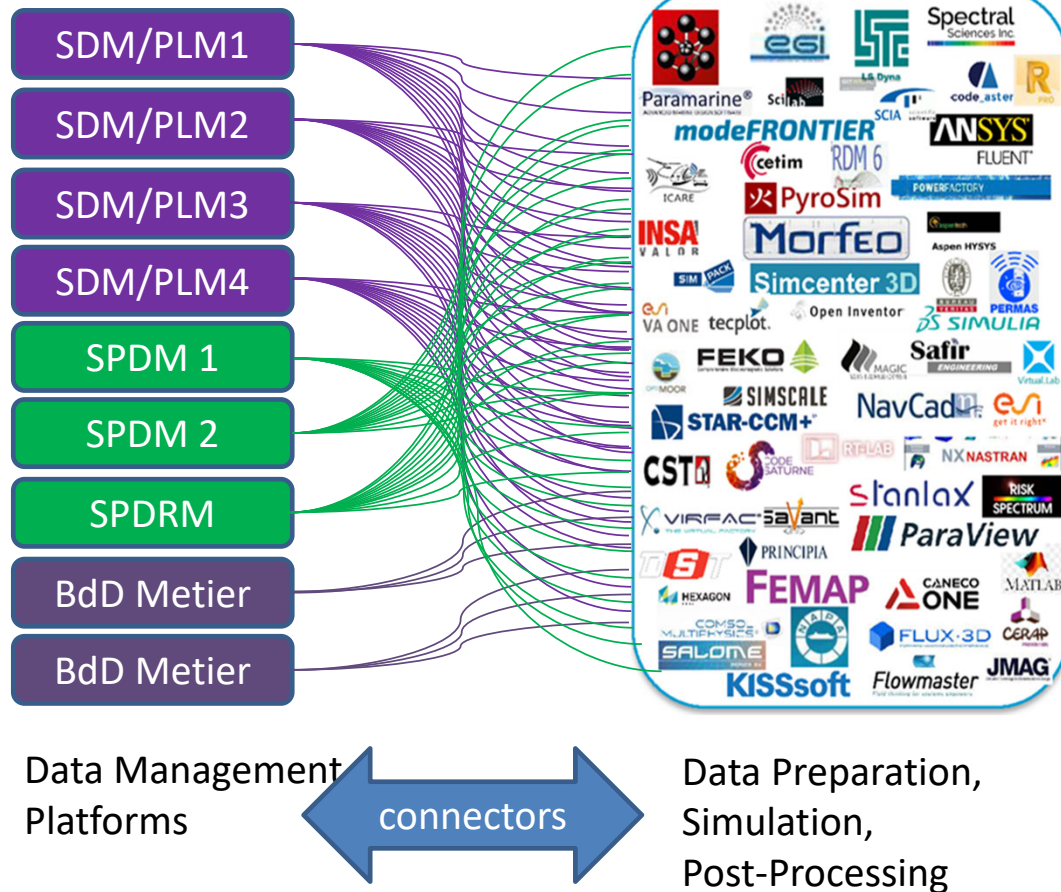
PDM: many 1000s of people 1 application

SDM: 10s to 100s of people 100+ applications

With thanks to Adrian Murton

With thanks to Naval Group

Cost of integrations between 100's of CAE desktop applications and platforms is a **major obstacle**

Data Management Platforms ←→ connectors ←→ Data Preparation, Simulation, Post-Processing

Current Technology:

- Development of point to point, API to API, connectors

- **30 to 80** connectors need to be developed for an enterprise project

- Connectors need multiple versions and frequent updates

- Competences on both data platform and CAE application APIs are rare

- Conflicts between vendors, difficult to test

- Connectors specific to a platform

- **~800 connectors** needed for industry coverage

- **A major obstacle to digital engineering**

Next steps to accelerate SPDM adoption as seen by a practitioner

Challenges

- Speed of deployment

- CAE application integration

- Access to best practice thinking

- Expertise shortage

Solutions

- New methodologies: "How to get started with SDM" publication
1. Integration of PIDO and/or
2. A standard application integration approach, implementable by a simulation methods team

- NAFEMS SPDM Best Practices Team

- Education and training, open source SDM availability

How to get started with Simulation Data Management

https://www.nafems.org/publications/resource_center/ht52/

"Having read the book from cover to cover, I now feel far more equipped to make serious decisions about how to instantiate a digital thread around our engineering design systems. Based upon 20+ years of industry success (and failure) in managing simulation data, this is an insightful guide for any organisation that plans to leave behind the 98% who currently don't exploit SPDM policies and infrastructure. To design and optimize the complex engineering solutions that will deliver a Net Zero planet, and to certify those products "in-silico", SPDM must be treated as a supporting pillar of the engineering design process. Mark's book is a clearly written primer, pointing any serious engineering company towards a digitally enabled future".
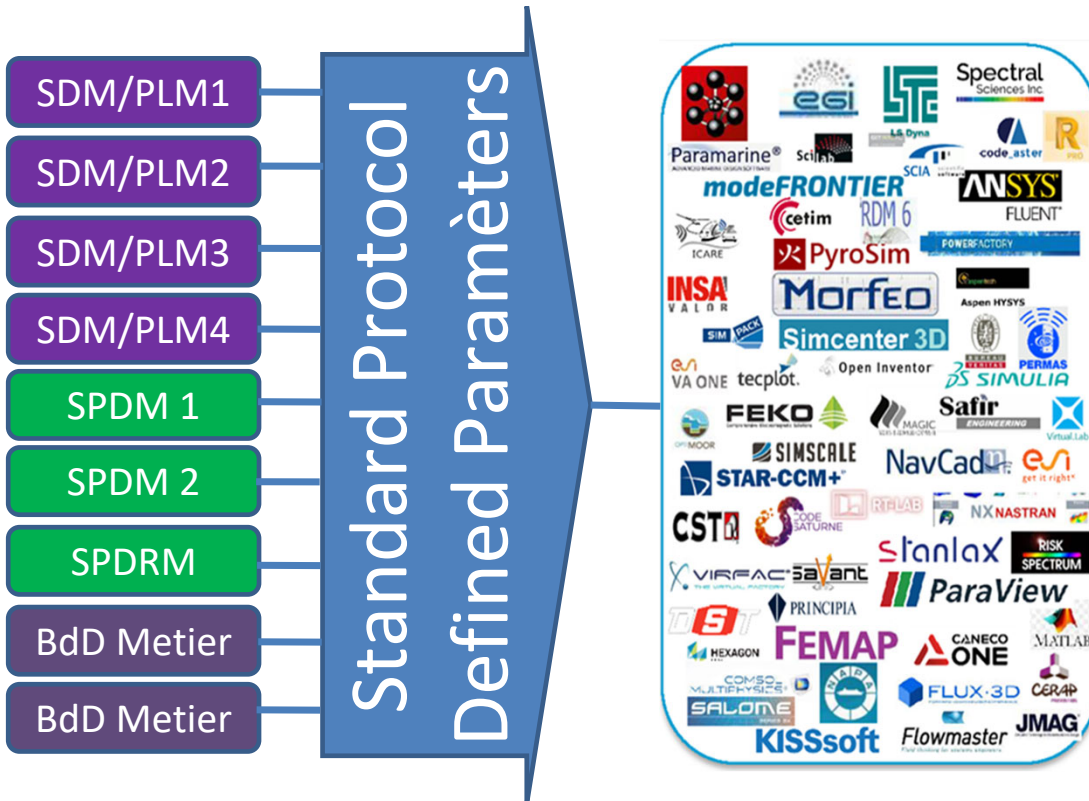
Dr. Rob Akers

Head of Advanced Computing
United Kingdom Atomic Energy Authority
Culham Science Centre

UK Atomic Energy Authority
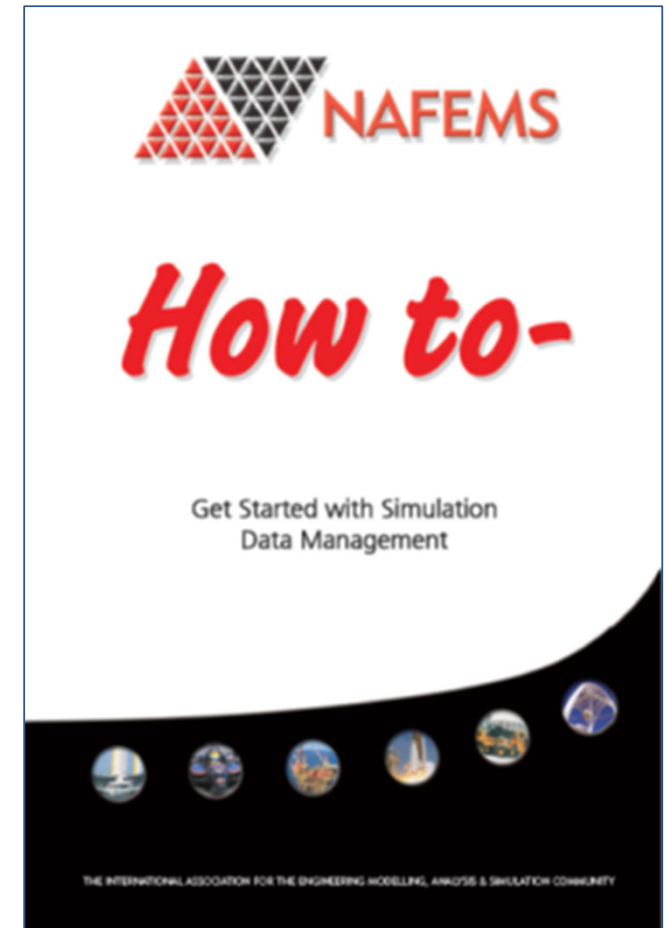
A standard approach, like FMI, will enable affordable integration of hundreds of interactive applications

SDM/PLM1
SDM/PLM2
SDM/PLM3
SDM/PLM4
SPDM 1
SPDM 2
SPDRM
BdD Metier
BdD Metier

**Standard Protocol Defined Parameters**

Technology under development:
- Standard specification
  - Standard exchange protocol
  - Defined Parameters & file format
- Development competences in application scripting are available: Methods departments, engineers, integrators, application vendors,…..
- Independence of complex platform APIs
- Connectors re-usable between projects and platforms
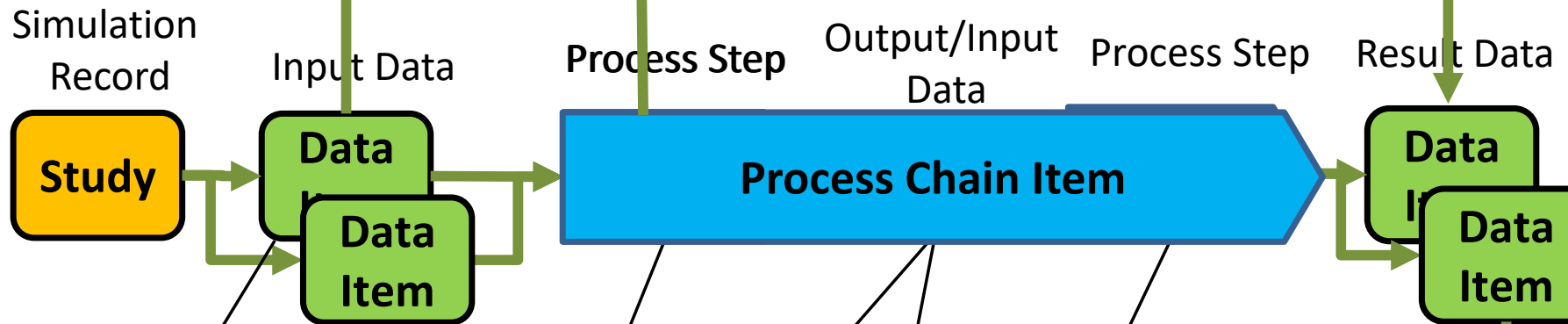- 10 times less expensive, saving of €000,000s per project

SDM + PIDO
a proven approach
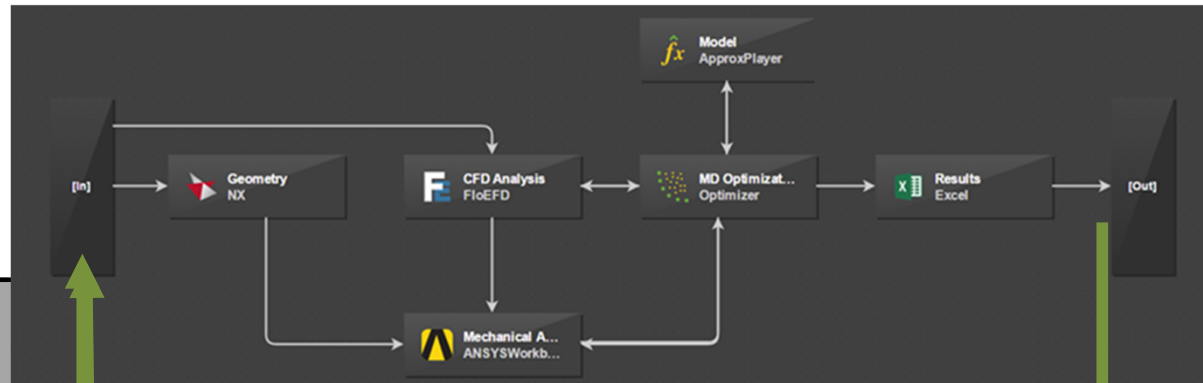
SDM 101

Interface layer: Web UI, CAE Applications, Add-ons, Systems, HPC

Meta-data layer: Items, Properties, Relationships, People & Orgs

Simulation Record

Input Data

Process Step

Output/Input Data

Process Step

Result Data

| Study | Data Item | Process Chain Item | Data Item |

Physical data layer: Files

Conclusion

- Levering P7's process modelling and integration framework will accelerate SDM deployment
  - CAE application integrations already available
  - Integrate 1 application instead of 30+
- Simulation results can be used directly to build surrogate models in P7
- Direct CAE application integration can then support ad-hoc simulation activities

Thank you for your attention

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