Taighde Éireann
Research Ireland

LC/NC platforms and AI: which future?

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WAVE CRT·AI I-Form Advanced Manufacturing Research Centre LERO Software for a better world UNIVERSITY OF LIMERICK OLLSCOIL LUIMNIGH Health Research Institute GREATLEAP

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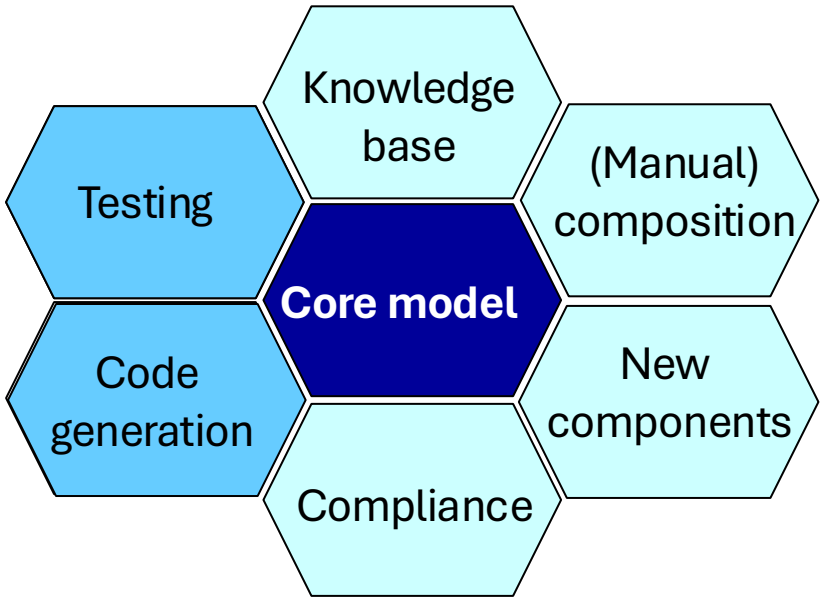
- **LC/NC and formal models**
- Examples
- LC/NC platform and architecture
- LC/NC and AI

"How could we **join our FM/Verif forces** in a setting like this?"

Service Centered Continuous Engineering Ingredients

Models

- formal (mathematical)
- properties
- model checking
- transformation (to code)
- model extraction



Genesys

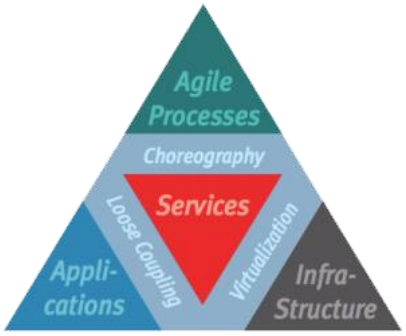
- model-to-model and model-to-code transformation

ITE

- model-based automated testing environment

LearnLib

- model inference by active automata learning



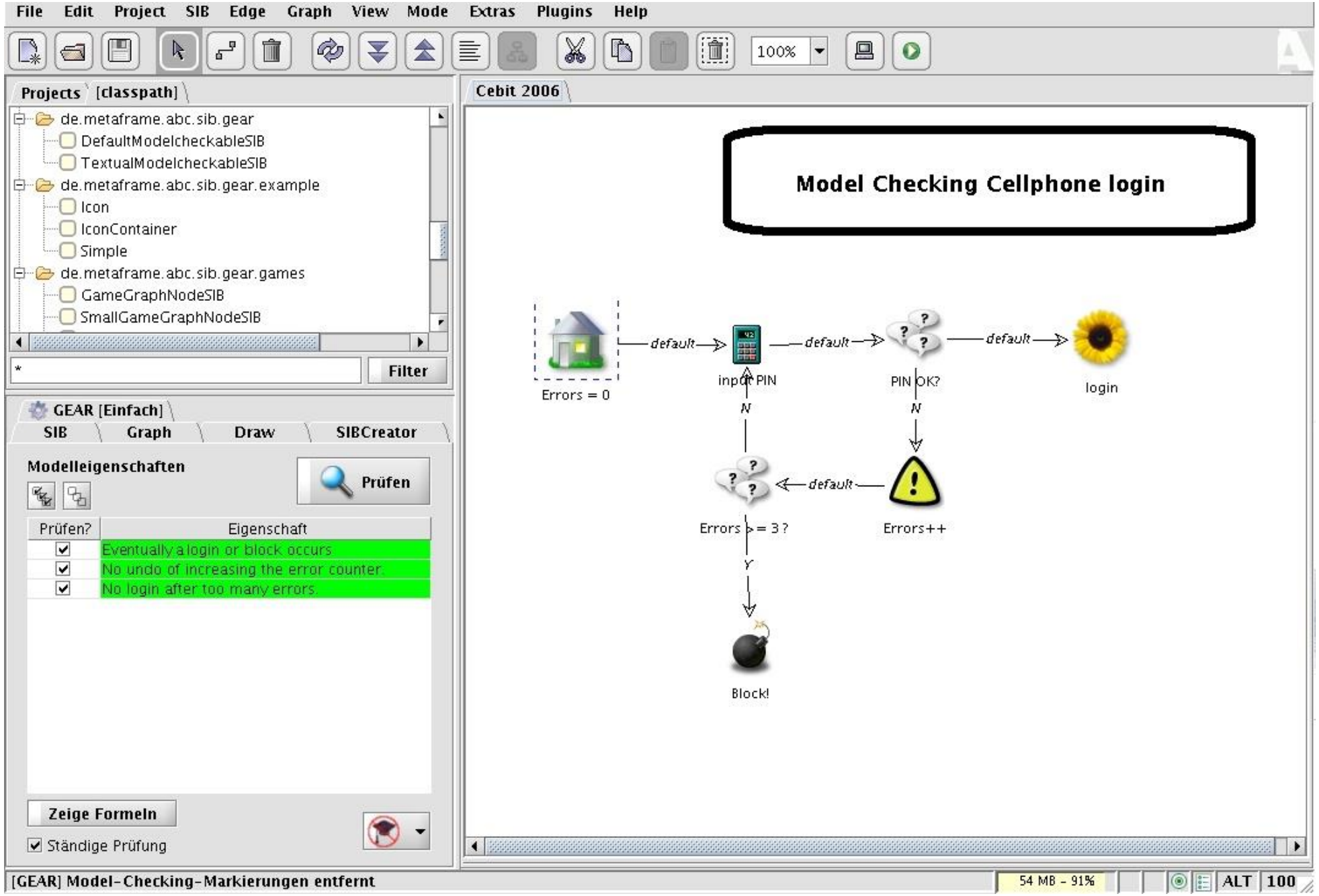
Frequent Experience with MDD

- Use cases which drive design & implementation
- Models which abstract the system
- Mapping between the models
- Static view in most of the models

and the main insufficiencies are:

- The lack of synchronization between the models
- The impact of changes is not immediately obvious
- No possibility to validate business rules & workflows

Automatic service composition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100%
Projects [classpath]
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TextualModelcheckableSIB
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Icon
IconContainer
Simple
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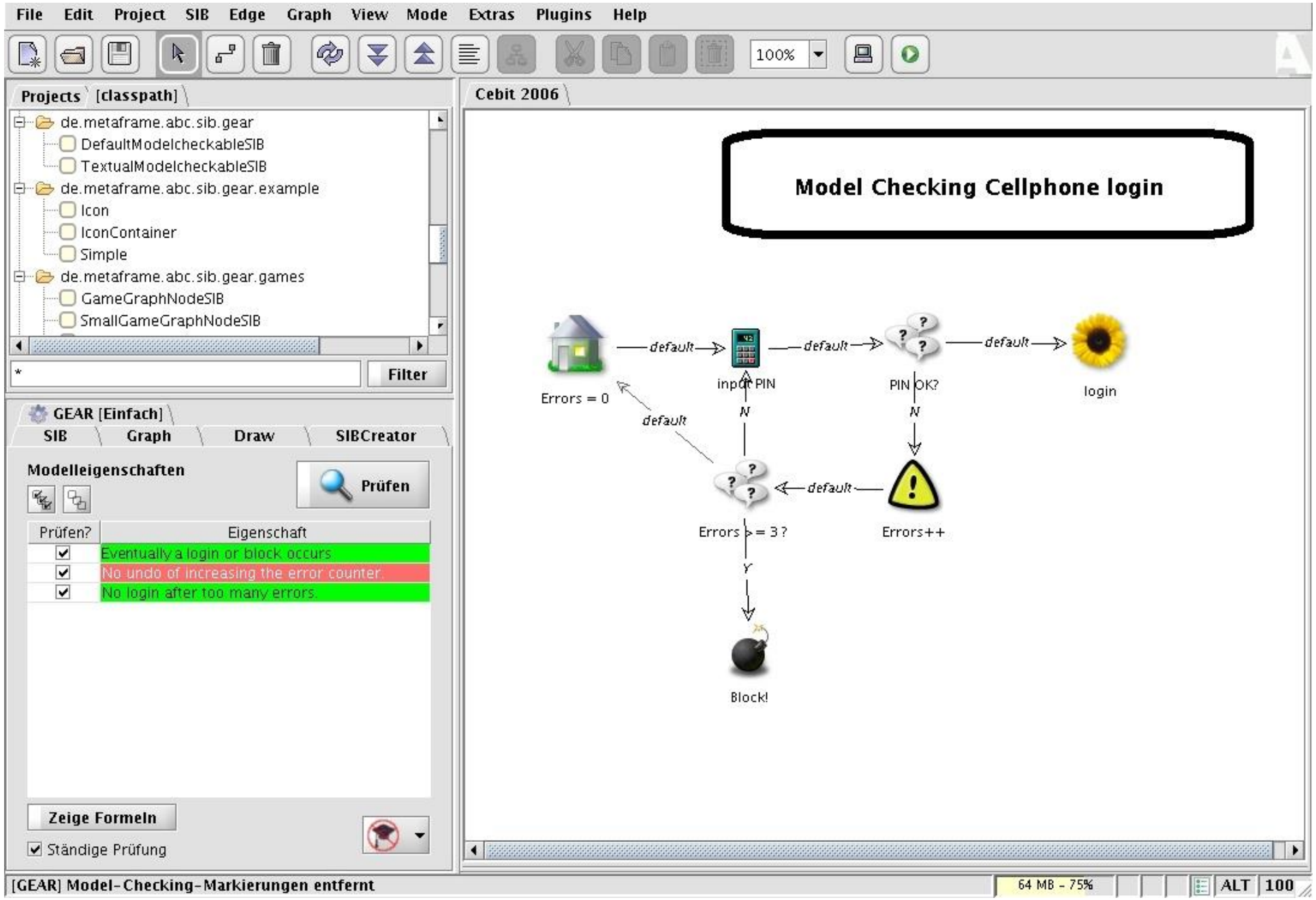
GameGraphNodeSIB
SmallGameGraphNodeSIB
Filter
GEAR [Einfach]
SIB Graph Draw SIBCreator
Modelleigenschaften
Prüfen
Prüfen? Eigenschaft
Eventually a login or block occurs
No undo of increasing the error counter
No login after too many errors
Zeige Formeln
Ständige Prüfung
Cebit 2006
Model Checking Cellphone login
default
Errors = 0
input PIN
PIN OK?
login
N
Errors >= 3 ?
Errors++
Y
Block!
[GEAR] Model-Checking-Markierungen entfernt
54 MB - 91%
ALT 100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Model Checking Cellphone login
default
input PIN
PIN OK?
login
Errors = 0
N
Errors >= 3 ?
Errors++
Y
Block!
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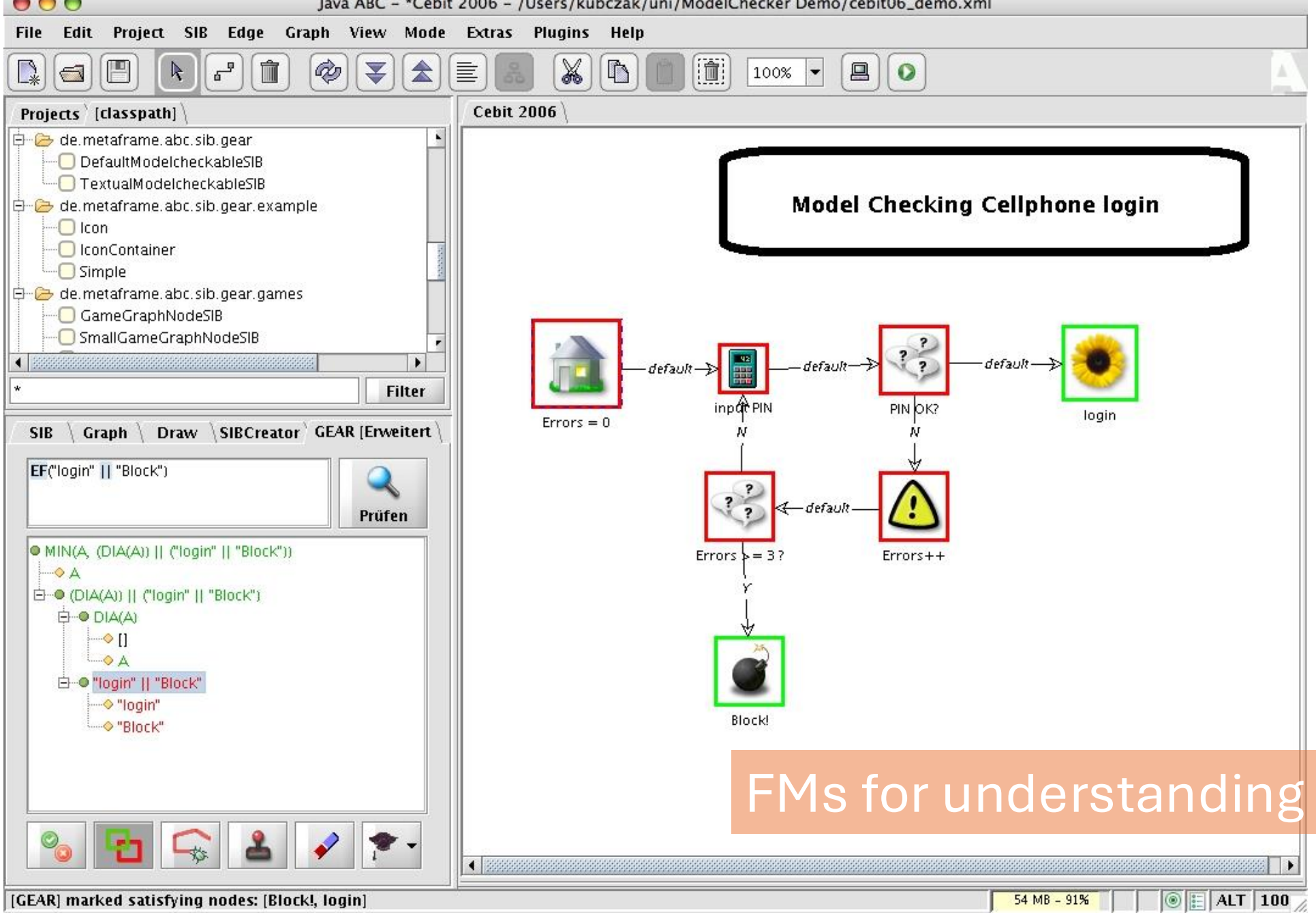
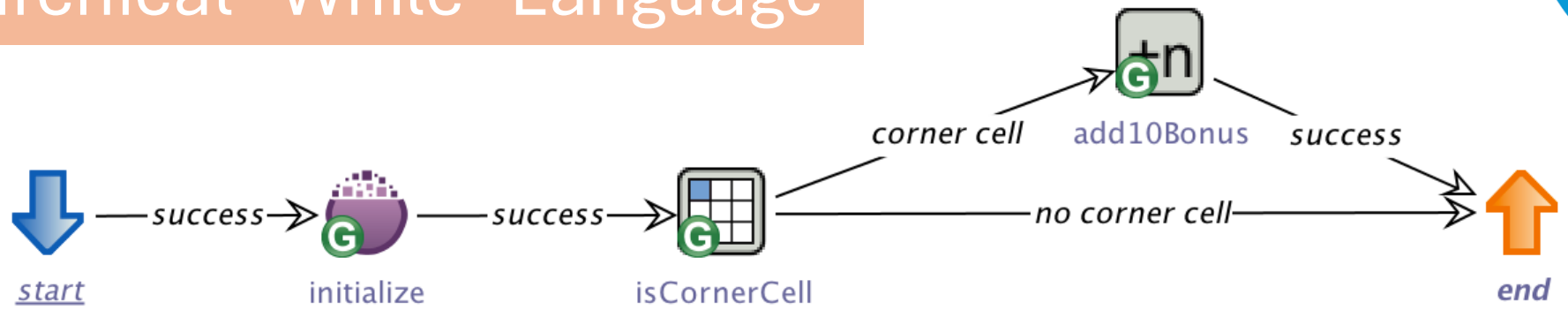


FMs for understanding models

Service Logic Graphs (SLGs)

Hierarchical “While” Language



A **Service Logic Graph (SLG)** is a 4-tuple $T=(S, s_0, Act, Trans)$ with:

S	a set of SIBs
s_0	a unique „Start SIB“
Act	a set of possible branching conditions
$Trans = \{(s,a,s')\}$	a set of transitions where $s,s' \in S$ and $a \in Act$.

ITU-T Q1200 Series

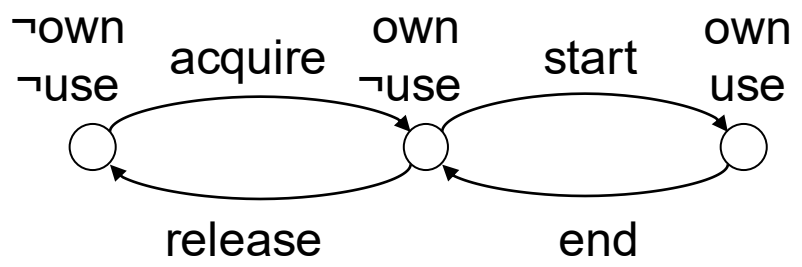
Q1200E.ZIP	26KB	09/97	Q.1200 - General series Intelligent Network Recommendation structure
Q1201E.ZIP	175KB	10/92	Q.1201 - Principles of intelligent network architecture

- SIB = reusable component
- SLG = application logic
- Formal semantics of SIBs and SLGs in SDL
- 4 levels of abstraction

This is how **interoperable telecommunications systems** work to this very day!

Q1200E.ZIP	26KB	09/97	Q.1200 - General series Intelligent Network Recommendation structure
Q1201E.ZIP	175KB	10/92	Q.1201 - Principles of intelligent network architecture
Q1202E.ZIP	86KB	X	Q1202 - Title not available.
Q1203E.ZIP	57KB	X	Q1203 - Title not available.
Q1204E.ZIP	99KB	03/93	Q.1204 - Intelligent network distributed functional plane architecture
Q1205E.ZIP	89KB	03/93	Q.1205 - Intelligent network physical plane architecture
Q1208E.ZIP	28KB	09/97	Q.1208 - General aspects of the Intelligent Network Application protocol
Q1210E.ZIP	25KB	10/95	Q.1210 - Q.1210-series Intelligent network Recommendation structure
Q1211E.ZIP	133KB	03/93	Q.1211 - Introduction to intelligent network capability set 1
Q1213E.ZIP	93KB	10/95	Q.1213 - Global functional plane for intelligent network CS-1
Q1214~1E.ZIP	412KB	10/95	Q.1214 Part ~1 - Distributed functional plane for intelligent network CS-1
Q1214~2E.ZIP	261KB	10/95	Q.1214 Part ~2 - Distributed functional plane for intelligent network CS-1
Q1214~3E.ZIP	368KB	10/95	Q.1214 Part ~3 - Distributed functional plane for intelligent network CS-1
Q1214~4E.ZIP	372KB	10/95	Q.1214 Part ~4 - Distributed functional plane for intelligent network CS-1
Q1215E.ZIP	69KB	10/95	Q.1215 - Physical plane for intelligent network CS-1
Q1218d1E.ZIP	26KB	09/97	Q.1218 Addendum 1 - Definition for two new contexts in the SDF data model
Q1218~1E.ZIP	115KB	10/95	Q.1218 Part ~1 - Interface Recommendation for intelligent network CS-1
Q1218~2E.ZIP	72KB	10/95	Q.1218 Part ~2 - Interface Recommendation for intelligent network CS-1
Q1218~3E.ZIP	241KB	10/95	Q.1218 Part ~3 - Interface Recommendation for intelligent network CS-1
Q1218~4E.ZIP	38KB	10/95	Q.1218 Part ~4 - Interface Recommendation for intelligent network CS-1
Q1218~5E.ZIP	39KB	10/95	Q.1218 Part ~5 - Interface Recommendation for intelligent network CS-1
Q1218~6E.ZIP	389KB	10/95	Q.1218 Part ~6 - Interface Recommendation for intelligent network CS-1
Q1218~7E.ZIP	181KB	10/95	Q.1218 Part ~7 - Interface Recommendation for intelligent network CS-1

Kripke Transition System (KTS)



Let *AP* be a set of atomic propositions.
A **Kripke Transition System** over *AP is a 4-tuple* *K*=(*S,Act Trans,I*) with:

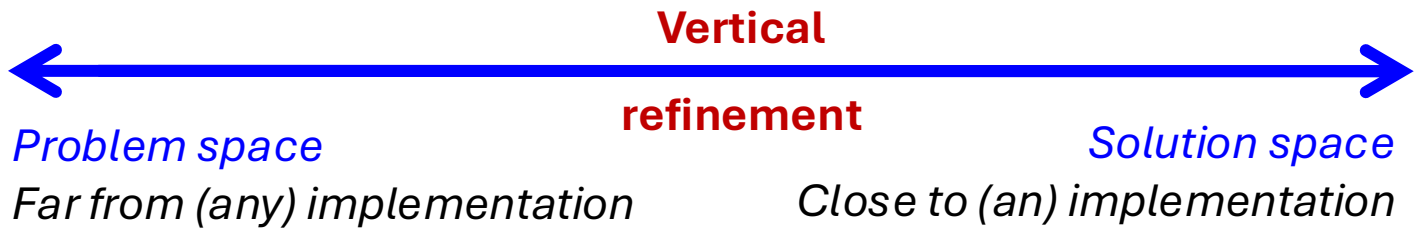
S	a set of states
Act	a set of actions
$Trans \subseteq S \times Act \times S$	a transition relation
$I: S \rightarrow 2^{AP}$	an interpretation function

Process oriented view

- **Process/Control flow : the „stories“ of the system**
  - Sequences of Activities (*flow of the controi from action to action*)
    - *How* to use the system?
    - *How* to implement functions?
- different abstraction levels:

Business process models
– actions in a business/operational course of coarse granular actions

Program execution models
– sequences of commands in a program (applicaiton)
– fine granular



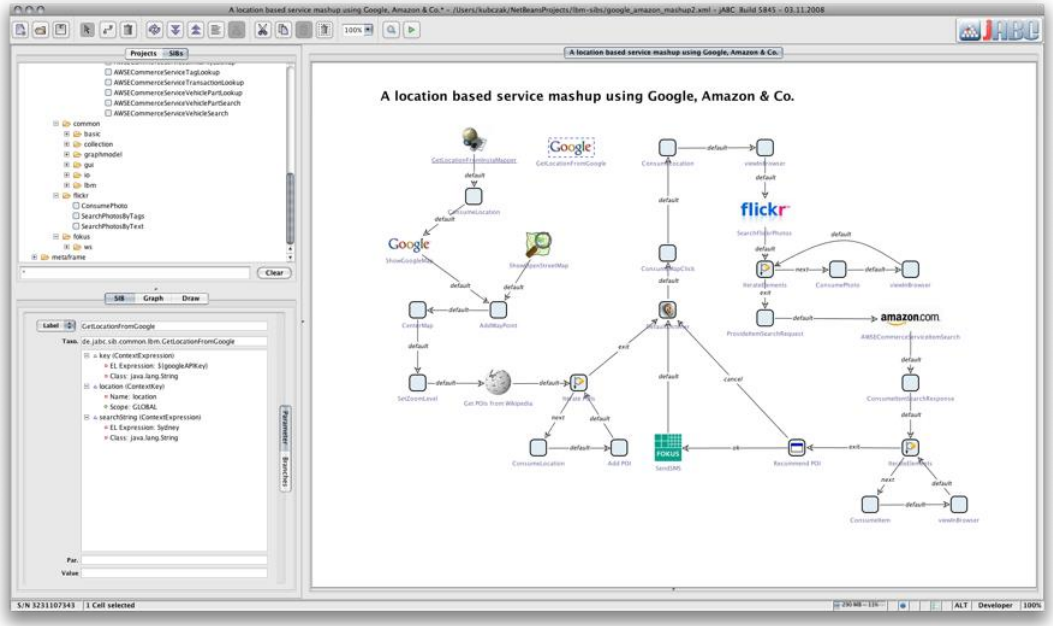
Mashups – CeBIT 2009

amazon.com
WSDL

flickr
REST

REST

Google
REST



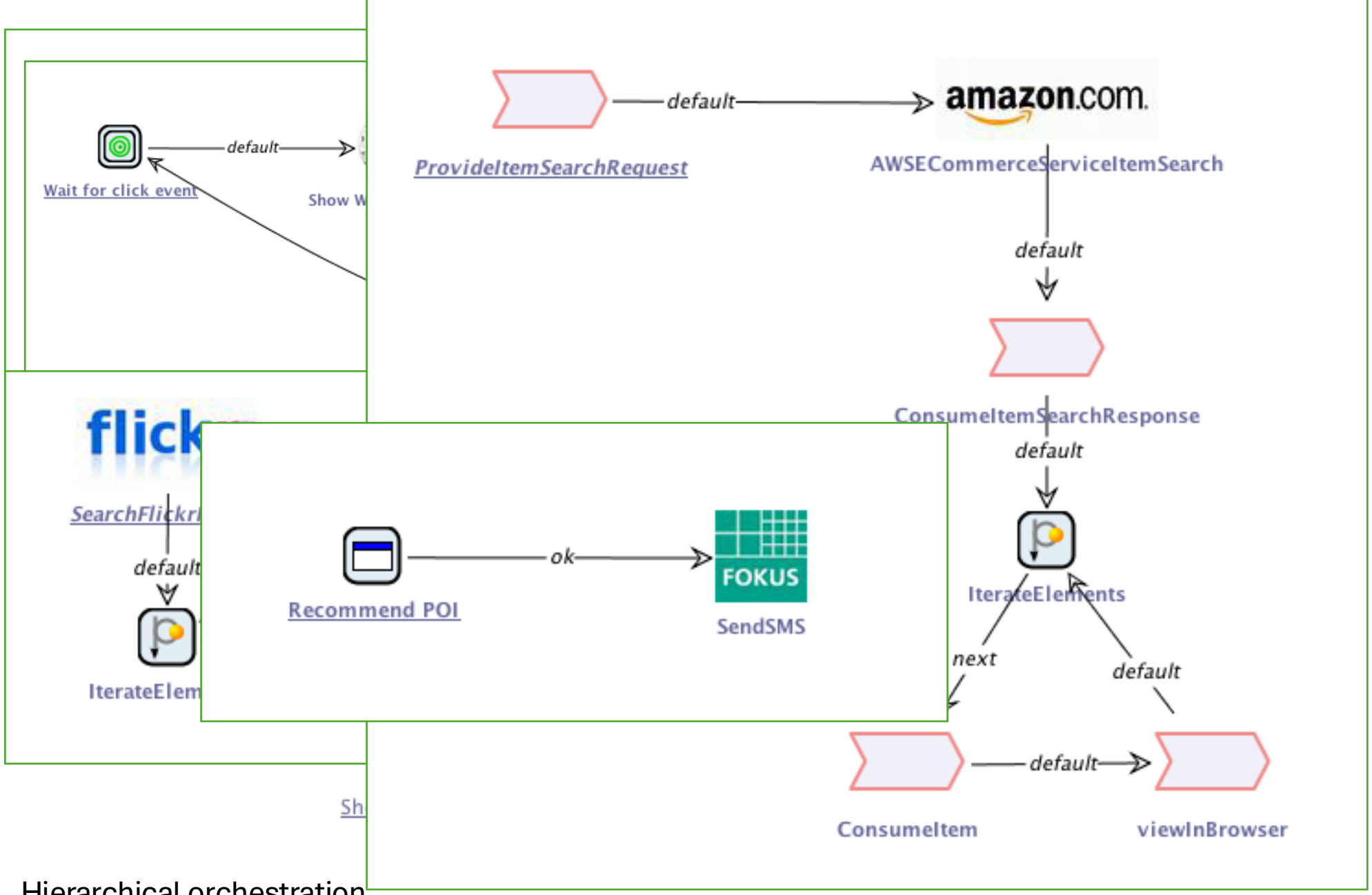
REST

REST

REST

FOKUS
WSDL

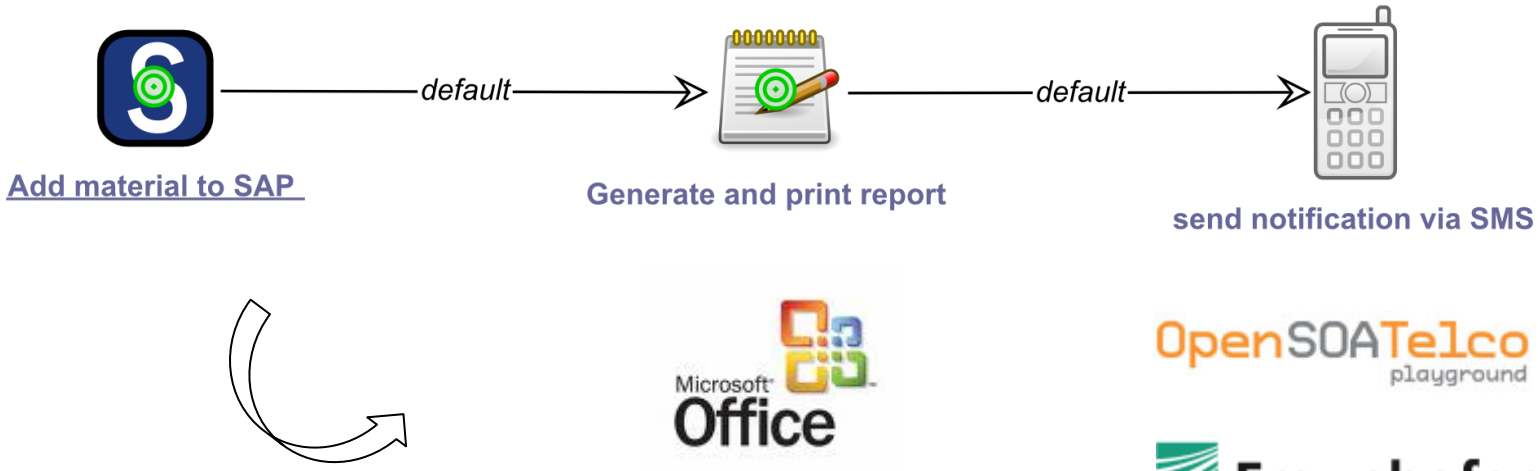
- Automatic service import
- Automatic composition synthesis with M2L and Golog [ISWC 2009]



Hierarchical orchestration

Mashups – CeBIT 2009

Enterprise Mashups for Product Lifecycle Management



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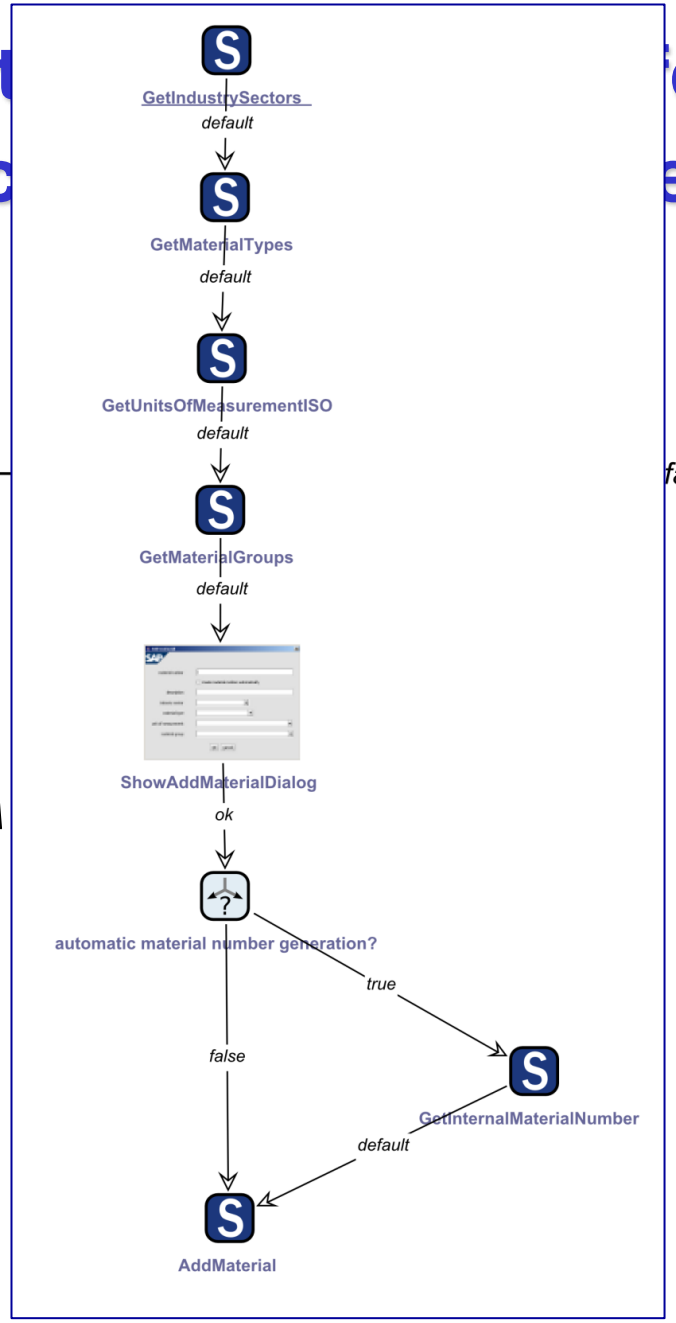


Add material to SAP

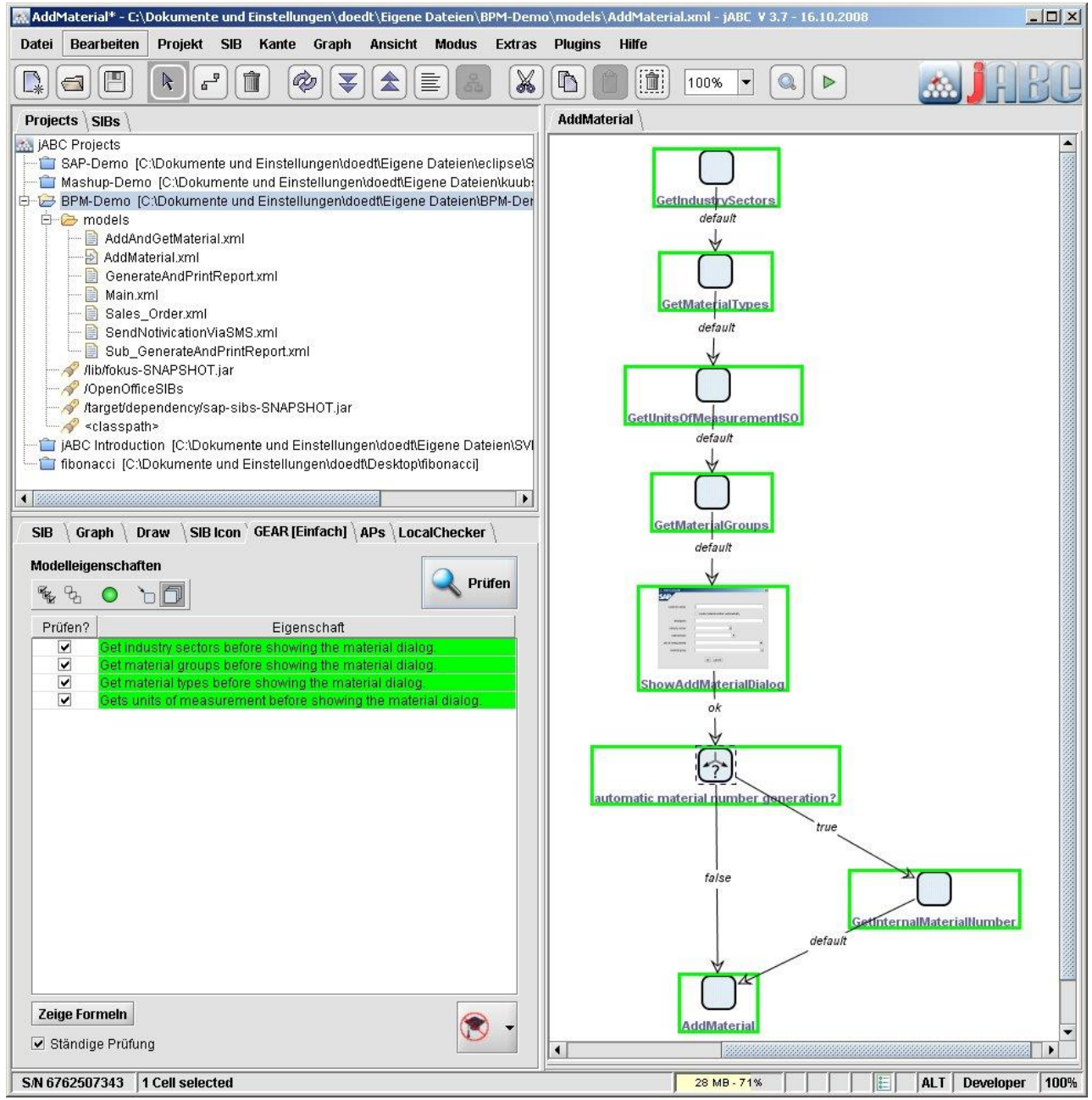
fault

send notification via SMS

OpenSOATelco playground

Fraunhofer FOKUS

Parlay-X services
(NGN IMS)



Business rules Compliance

(GEAR)

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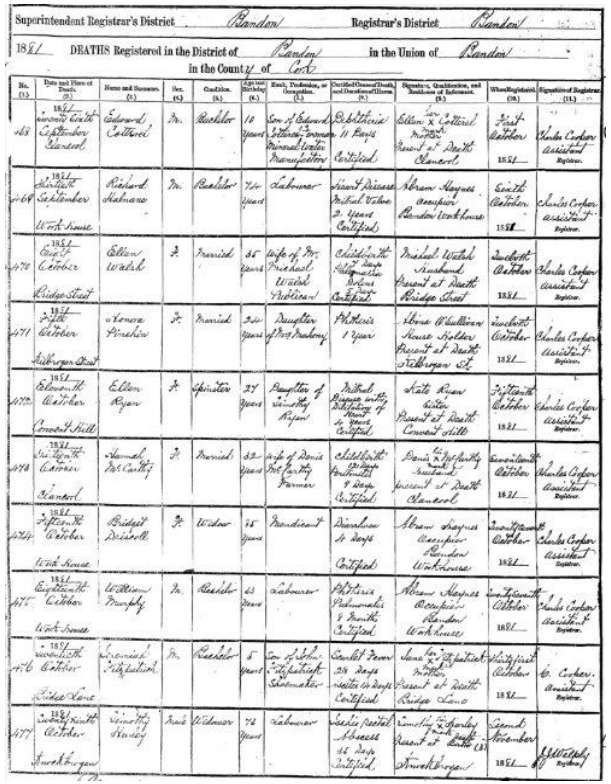
Death and Burial Data: Ireland 1864-1922



Machine readable extraction and linkage of file 4843239 in the 1881 GRO Ledger

	A	B	C	D	E	F	G	H	I	J	K
1	Group Registration ID	Deceased Forename	Deceased Surname	Deceased	Sex	SR District/Reg Area	Deceased Date of Death	Deceased Year of Death	Deceased Civil Status	Tiff File Path	Record Number
2	6775335	HONORA	PINCHIN	24	FEMALE	Bandon	N/A	1881	MARRIED	Deaths_Returns\deaths_1881\06418\4843239.tif	4
3	6419907	JEREMIAH	FITZPATRICK	5	MALE	Bandon	N/A	1881	BACHELOR	Deaths_Returns\deaths_1881\06418\4843239.tif	9
4	6553594	ELLEN	RYAN	27	FEMALE	Bandon	N/A	1881	SPINSTER	Deaths_Returns\deaths_1881\06418\4843239.tif	5
5	6310256	RICHARD	HALNANE	74	MALE	Bandon	N/A	1881	BACHELOR	Deaths_Returns\deaths_1881\06418\4843239.tif	2
6	6053536	ELLEN	WALSH	35	FEMALE	Bandon	N/A	1881	N/A	Deaths_Returns\deaths_1881\06418\4843239.tif	
7	6704817	TIMOTHY	HURLEY	73	MALE	Bandon	N/A	1881	WIDOWED	Deaths_Returns\deaths_1881\06418\4843239.tif	10
8	6387435	WILLIAM	MURPHY	33	MALE	Bandon	N/A	1881	BACHELOR	Deaths_Returns\deaths_1881\06418\4843239.tif	8
9	6105668	BRIDGET	DRISCOLL	85	FEMALE	Bandon	N/A	1881	WIDOWED	Deaths_Returns\deaths_1881\06418\4843239.tif	7
10	6667571	EDWARD	COTTEREL	10	MALE	Bandon	N/A	1881	BACHELOR	Deaths_Returns\deaths_1881\06418\4843239.tif	1
11	6761142	HANNAH	MCCARTHY	32	FEMALE	Bandon	N/A	1881	MARRIED	Deaths_Returns\deaths_1881\06418\4843239.tif	6

E. O'Shea, R. Khan, C. Breathnach and T. Margaria, "Towards Automatic Data Cleansing and Classification of Valid Historical Data An Incremental Approach Based on MDD," 2020 IEEE Int. Conf. on Big Data, 2020, pp. 1914-1923, doi: 10.1109/BigData50022.2020.9378148.

Enda O'Shea. "Machine Transcription Pipeline for Historical Irish Death Records". PhD thesis. University of Limerick, 2024.

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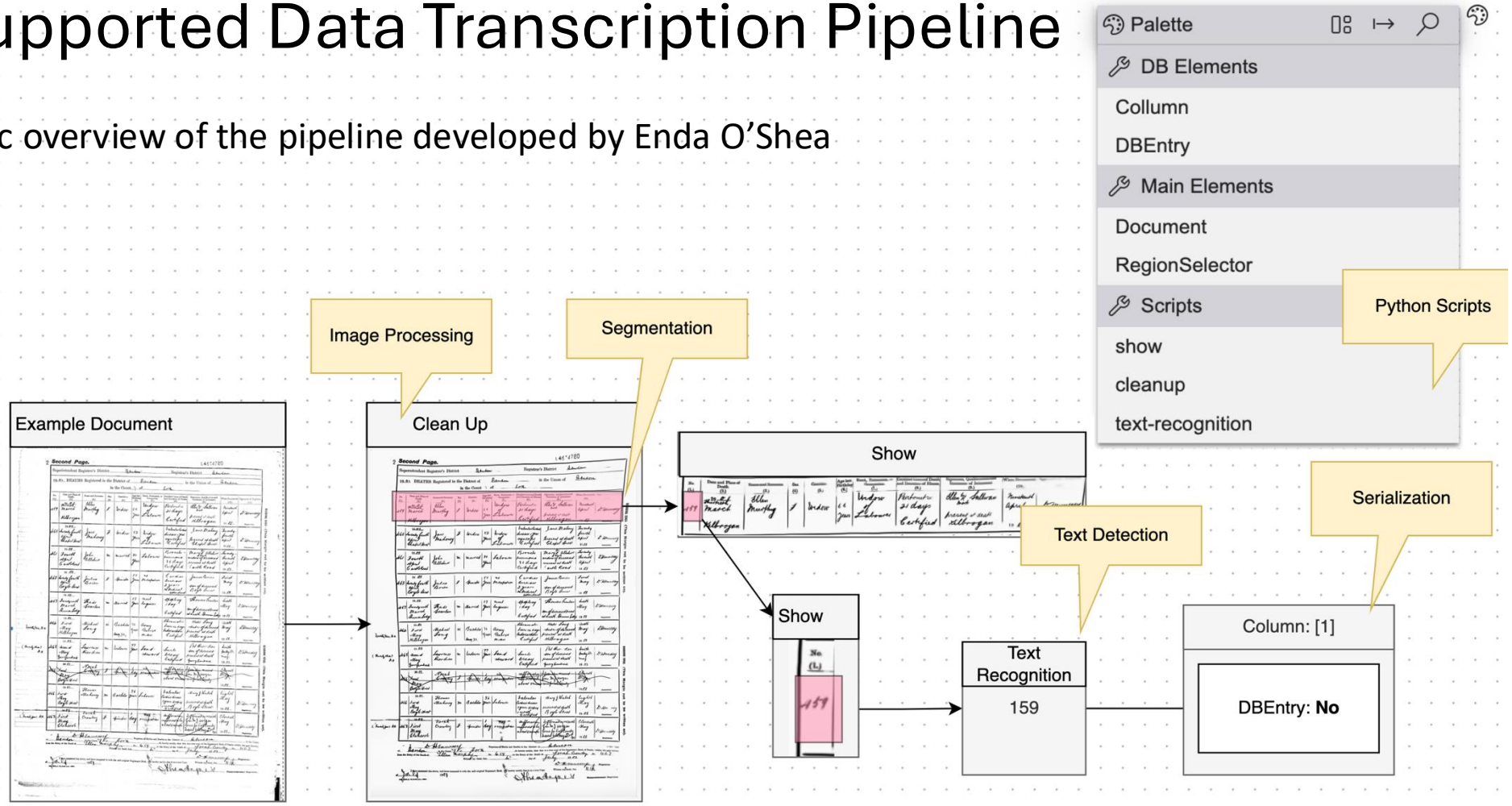
AI-Supported Data Transcription Pipeline

Schematic overview of the pipeline developed by Enda O'Shea



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Ollscoil na Gaillimhe
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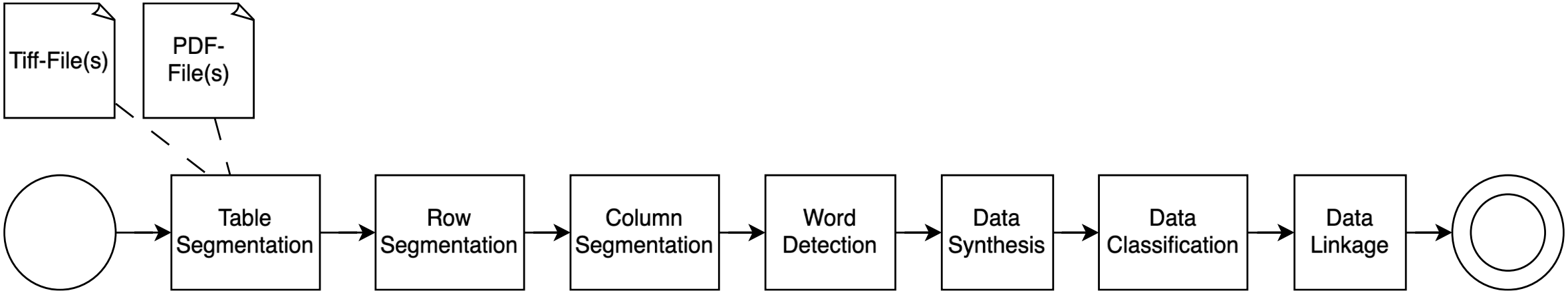
AI-Supported Data Transcription Pipeline

(Schematic overview of the pipeline developed by Enda O'Shea)



Problems and Challenges

- Current solution works great for subset of the data
- Other datasets may require (slight) alterations

- Pipeline is a manually executed mix of Python, Matlab and Shell scripts
- Execution needs to be orchestrated by the user themselves, this requires some coding knowledge
- Execution is local; users need to bring their own hardware

- **Adapting for different data sets is hard for non-developers!**

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The Great Leap

cost
EUROPEAN COOPERATION
IN SCIENCE & TECHNOLOGY

"Embracing the COST Mission, the Great Leap takes a unique, multidisciplinary approach from a historical perspective to gain a greater understanding of the roots and drivers of health inequalities across regions and countries in Europe and beyond. To achieve this mission, the Great Leap creates an international, multidisciplinary network that will bundle expertise, techniques, insights and data to create

(1) the first international comparable dataset of individual-level historical cause of death data,
(2) **innovative analytical tools to analyse it**, and
(3) insights into how this information can be used in current public health policy and practice."

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Low-Code / No-Code

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in Artificial Intelligence

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The WAVE PLATFORM:

Builds the **WAVE** LCNC platform

Advanced Low-code Development Environment

Digital Thread in Integrated Software and System Ecosystems

Cinco de Bio

Builds Applications

Programming Language Level - DSLs

Application Domain - DSLs

EPE Dissemination

Education, Publications, Impact in business and society

The Architecture:

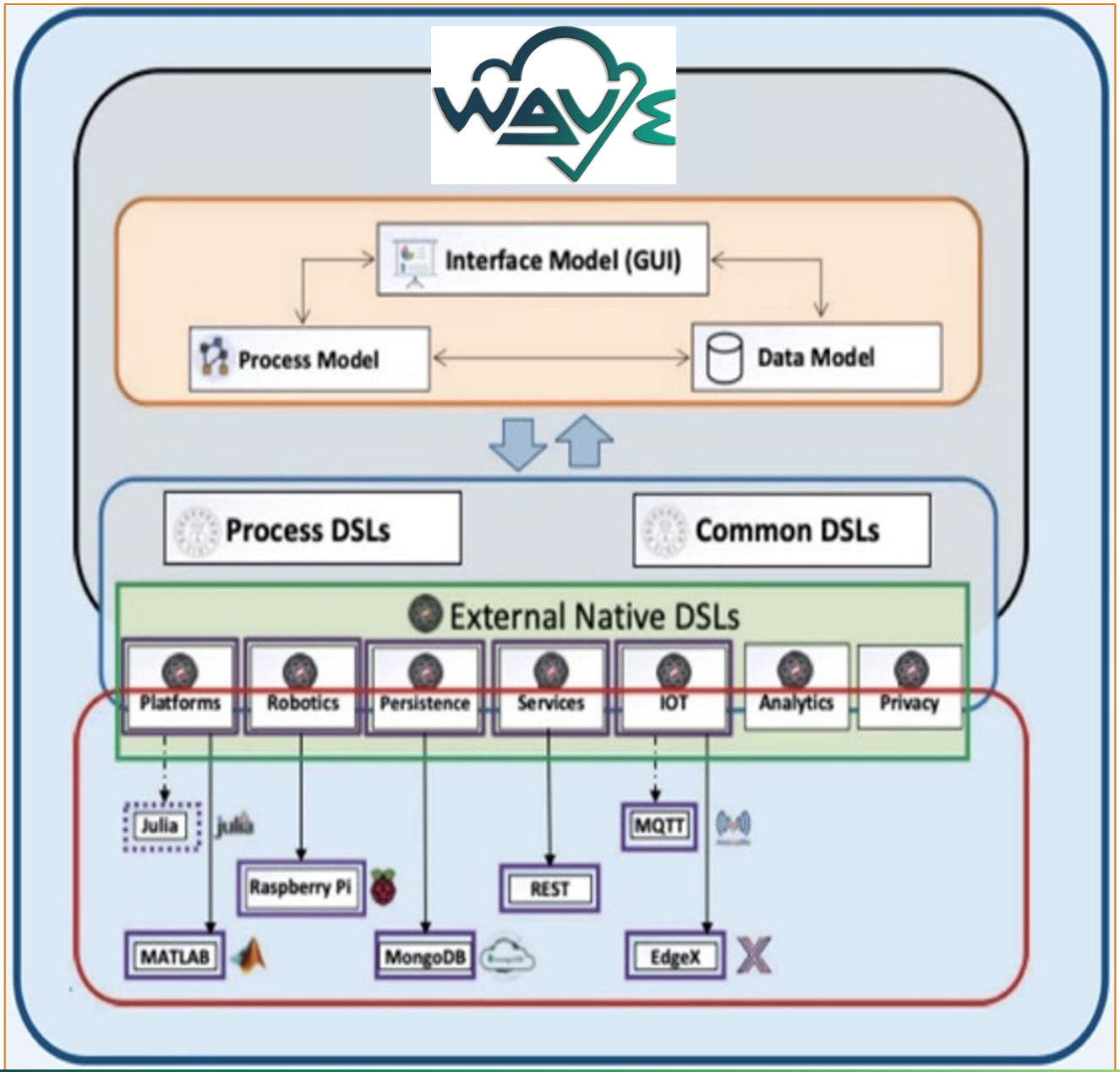
Programming Language – Domain Specific Languages
(PL-DSLs)
The general-purpose modelling languages

Use PL-DSL and AD-DSLs
to “create” applications and deploy them

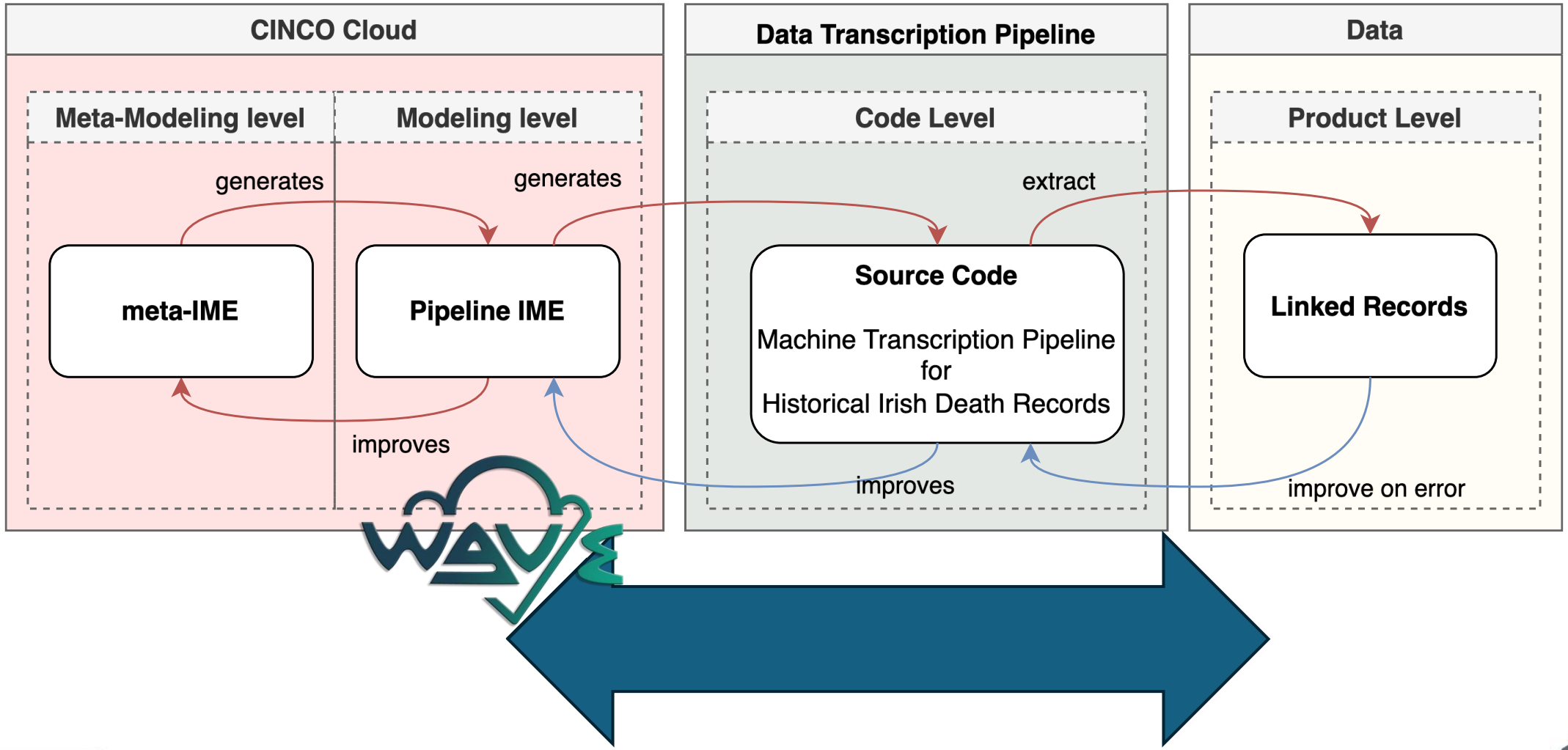
Application Domain – Domain Specific Languages
(AD-DSLs)

Integrate/add (new) functionalities/domains

Hardware, robots, IoT, algorithms, datasets, DBs, communication, AI,
cloud, edge, …



Low-Code / No-Code



Low-Code / No-Code

- Allows users without programming knowledge to create applications

- Utilizes **models** to express what to do and how, enabling formal guarantees
- Infers / generates **correct code** from the models (and other guidance) with minimal or no programming knowledge

- New **platforms** support this way of producing applications for a given research or application domain

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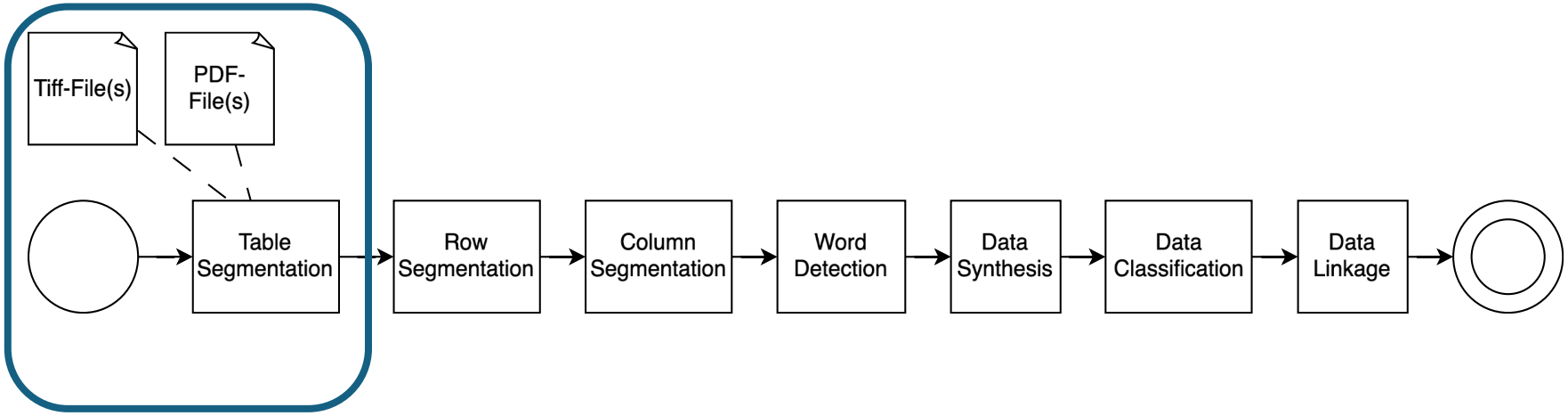
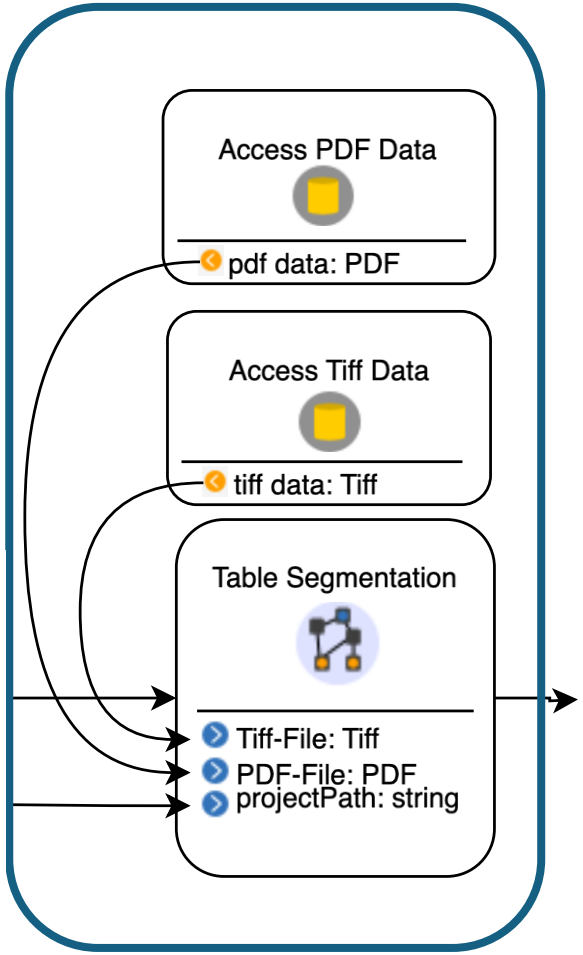
AI-supported Transcription Example





Varants, SPLs

From Proof-of-Concept to Modules

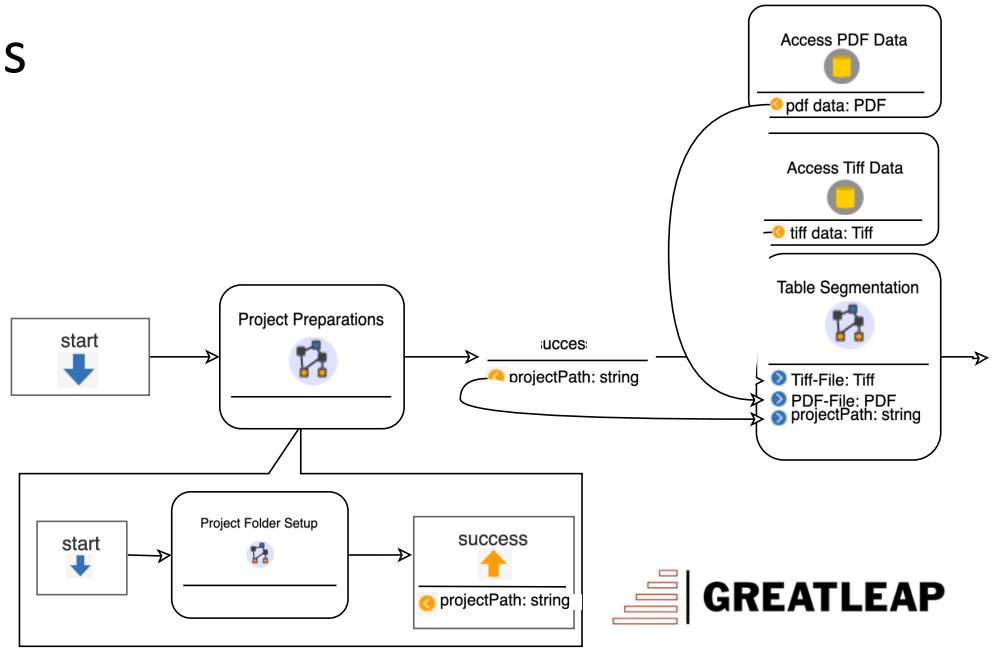
Proof of concept:

- Existing workflow cannot be easily automated
  - Modules have side effects that make separation difficult
  - No formal capture of dependencies, pre- and post-conditions
  - Weak separation of concerns
- Interaction with the user required; prompts need manual intervention and inputs

From Proof-of-Concept to Modules

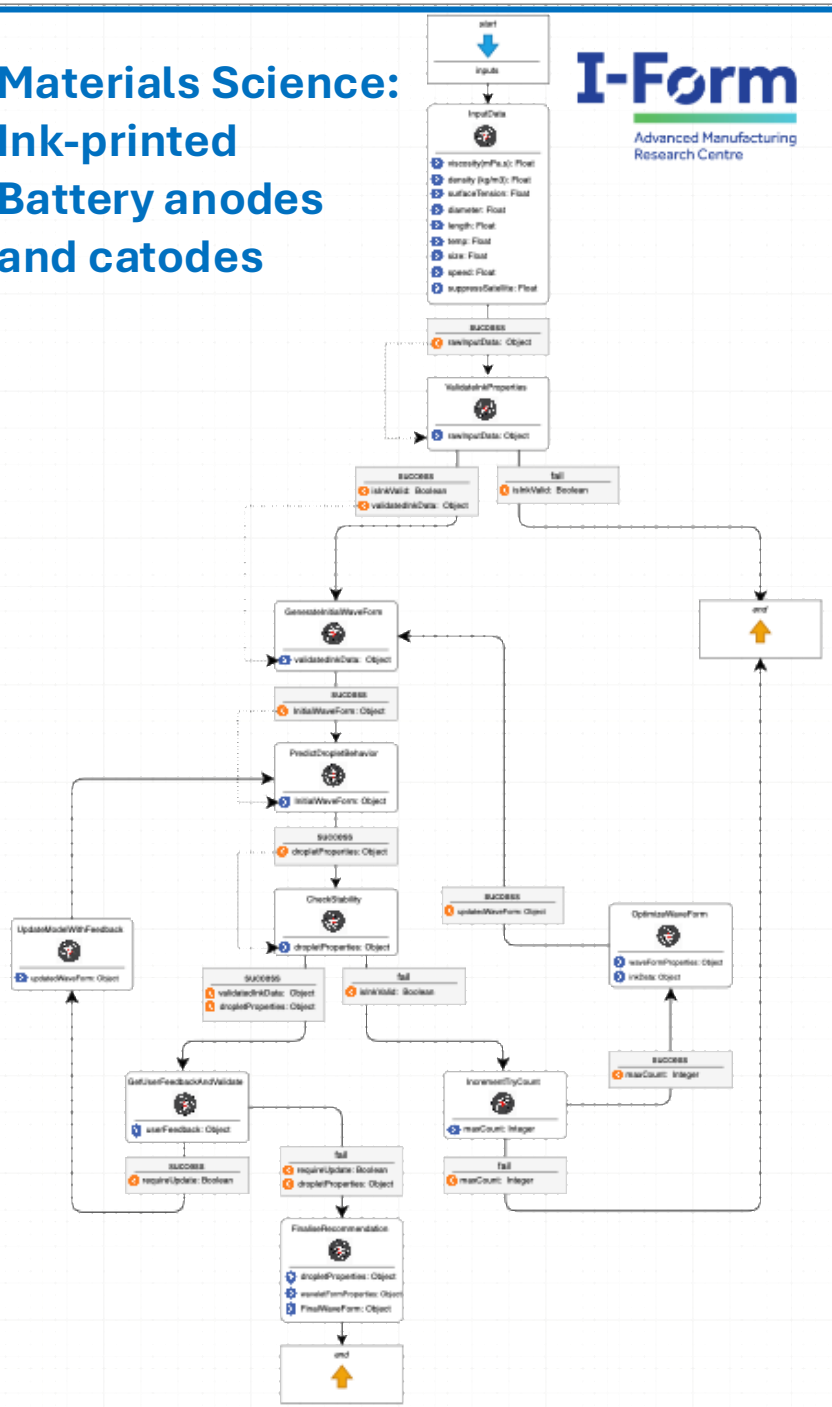
„Modules“:

- Transform the code into a **library-style collection** of well defined components
- By creating Service Independent Blocks (SIBs), workflows can be expressed as (f ormal) **models**
- Workflows are **(graphical) compositions** of SIBs
- **Generate** the complete code of the application from the SIBs and the workflows
- **Deploy and run** the application.



Materials Science: Ink-printed Battery anodes and catodes

I-Form
Advanced Manufacturing Research Centre



Blockchain: Token based cancer patient data protection

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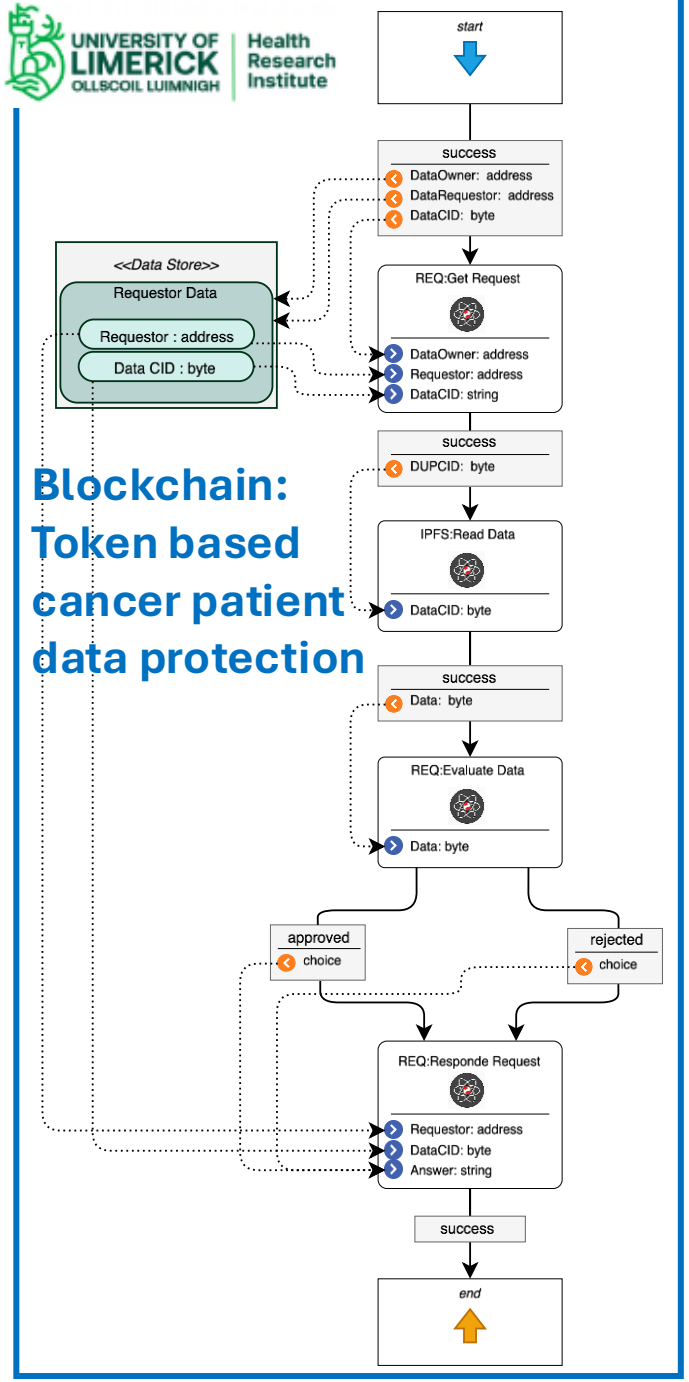
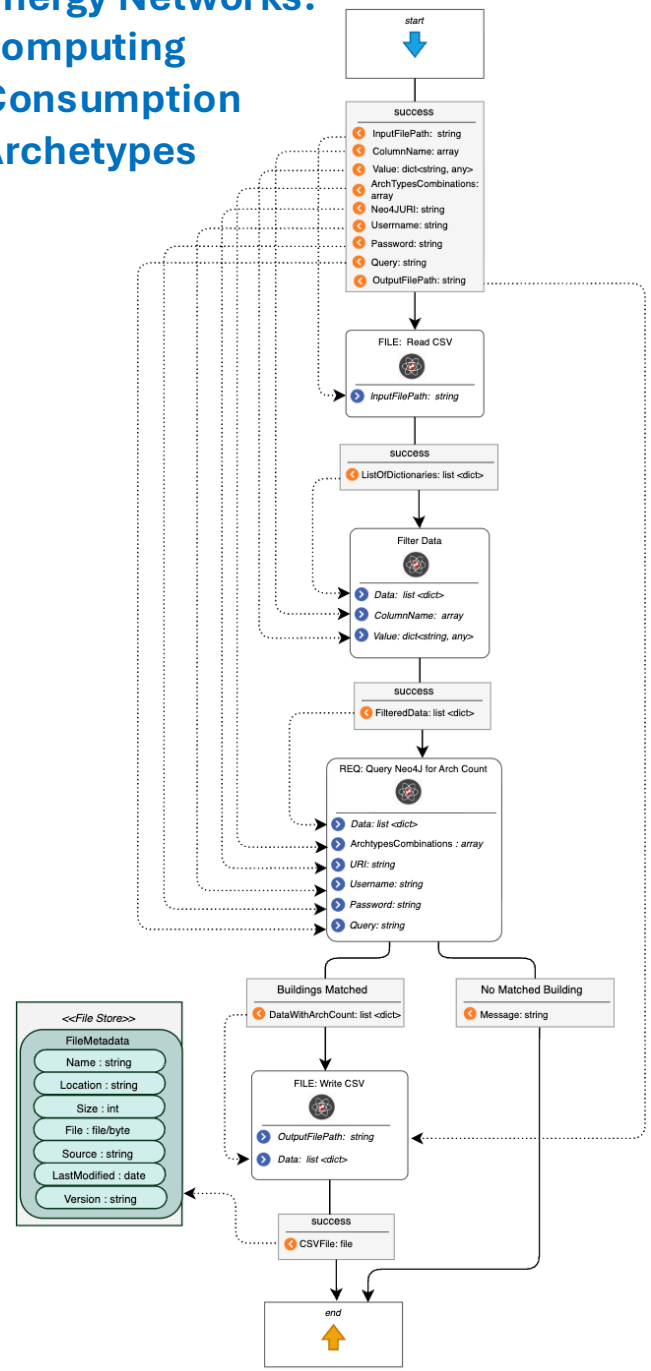
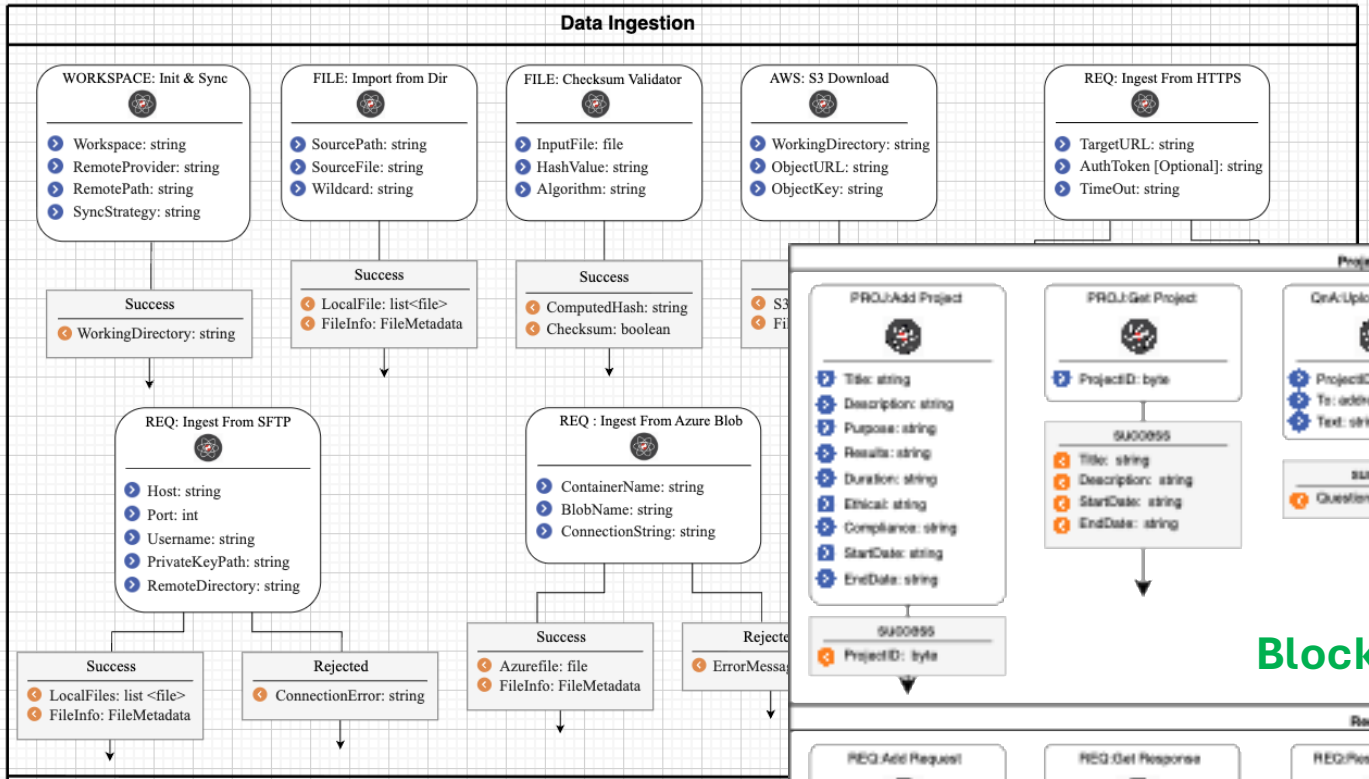
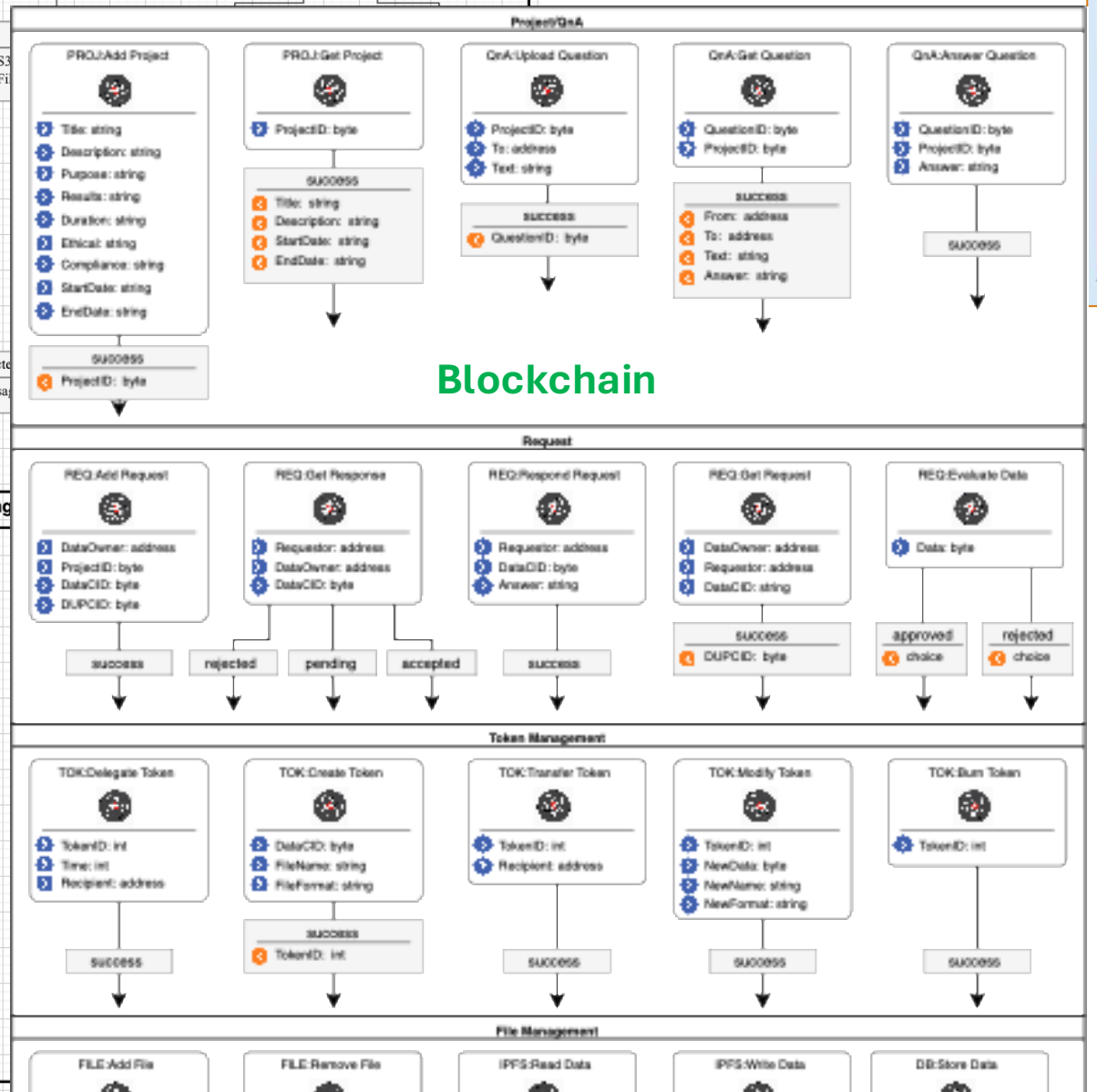
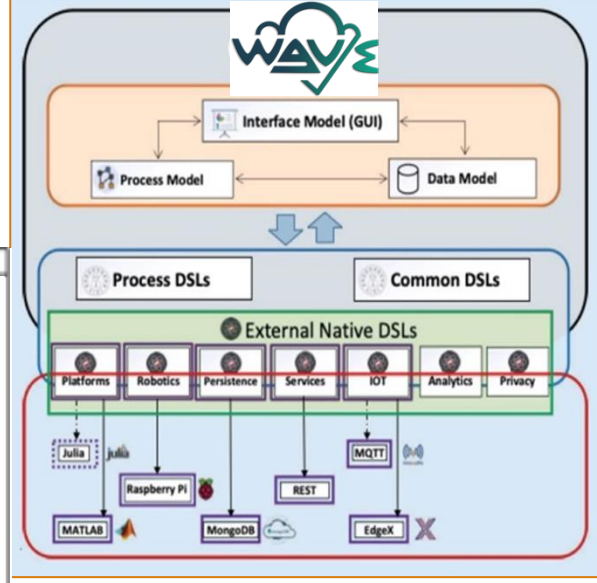


Energy Networks: computing Consumption Archetypes







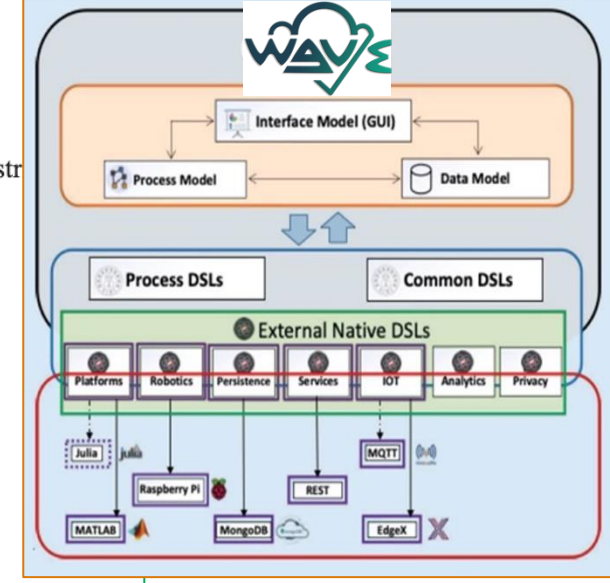


SIB Palettes (atomic components)

AD-DSLs

Energy management

- Native
  - common.sibs
    - WORKSPACE: Init & Sync (Workspace (string) RemoteProvider (string) RemotePath (string) SyncStrategy (string)) --> |success (WorkingDirectory (str
    - FILE: Import from Dir (SourcePath (string) SourceFile (string) Wildcard (string)) --> |success (LocalFile (list<file>) FileInfo (FileMetaData))|
    - FILE: Get File Source (FileSource (enum[AWS, Local])) --> AWS | Local
    - FILE: Checksum Validator (InputFile (string) HashValue (string) Algorithm (string)) --> |success (ComputedHash (string) Checksum (boolean))|
    - FILE: Get Format (InputFile (string)) --> zip_tar_archive (FileFormat (string) Encoding (string)) | Excel (FileFormat(string) Encoding (string)) | Txt (FileFormat (string) Encoding (string))|
    - ARCHIVE: Decompress (InputFile (file) Password(string)) --> |success (ExtractedFiles (list<files>)|
  - data_ingestion.sibs
    - AWS: S3 Download (WorkingDirectory (string) ObjectURL (string) ObjectKey(string)) --> |success (S3 File (file) FileInfo (FileMetadata))|
    - REQ: Ingest From HTTPS (TargetURL (string) AuthToken (string) Timeout(string)) --> |success (Downloaded File (file) FileInfo (FileMetadata))|
    - REQ: Ingest From SFTP (Host (string) Port (int) Username (string) PrivateKeyPath (string) RemoteDirectory (string)) --> |success (LocalFiles (list<file>) FileInfo (FileMetaData))|
    - REQ: Ingest From Azure Blob (ContainerName (string) BlobName (string) ConnectionString (string)) --> |success (LocalFiles (list<file>) FileInfo (FileMetadat))|
  - parsing_and_formatting.sibs
    - CONVERT: Convert Excel to CSV (InputXLS (file) Splitsheets (boolean)) --> |success (CSVFile (file))|
    - CONVERT: Convert Txt to CSV (InputTxt (file) Delimiter (char)) --> |success (CSVFile (file))|
    - TXT: Standardise Encoding (RawFiles (list <files>) TargetEncoding (string)) --> |success (EncodedFiles (list<file>))|
  - arch_count.sibs
    - FILE: Read CSV (InputFilePath (string)) --> |success (ListOfDictionaries (list <dict>))|
    - Data: Filter Data (Data (list <dict>) ColumnName (array) Value (dict <string, any>)) --> |success (FilteredData (list<dict>))|
    - REQ: Query Neo4J for Arch Count (Data (list <dict>) ArchTypesCombination (array) URI (string) Username (string) Password (string) Query (string)) -> Buildings Matched (DataWithArchCount (list <dict>)) | No Buildings Matched (Message (string))
    - FILE: Write CSV (OutputFilePath (string) Data (list <dict>)) --> |success (CSVFile (file))|



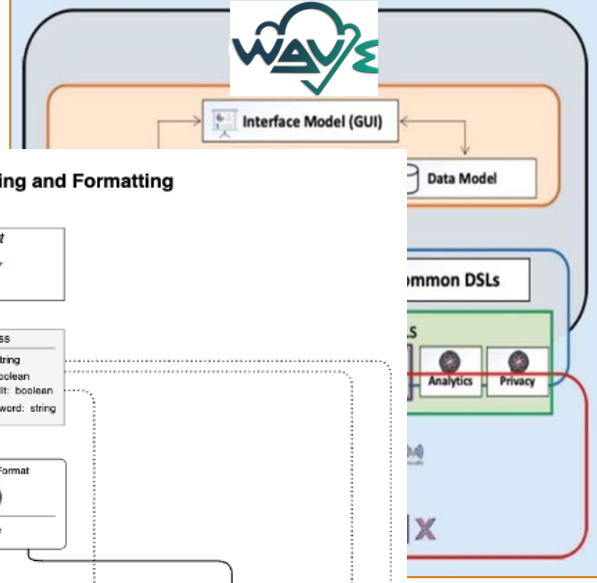
SIB Palettes (atomic components)

AD-DSLs

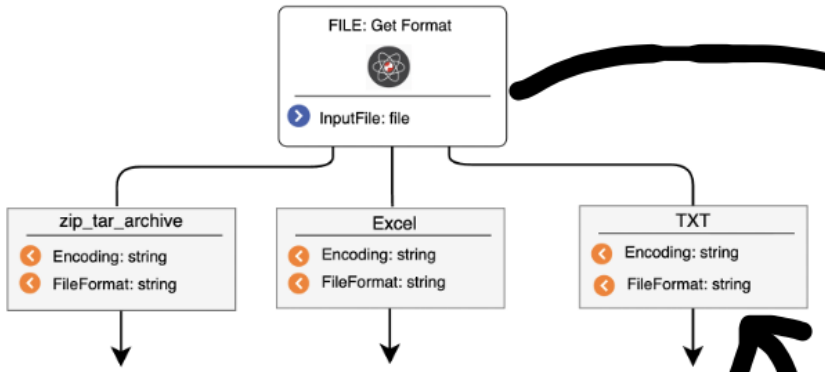
Energy management

SIB Palettes (atomic components)

AD-DSLs

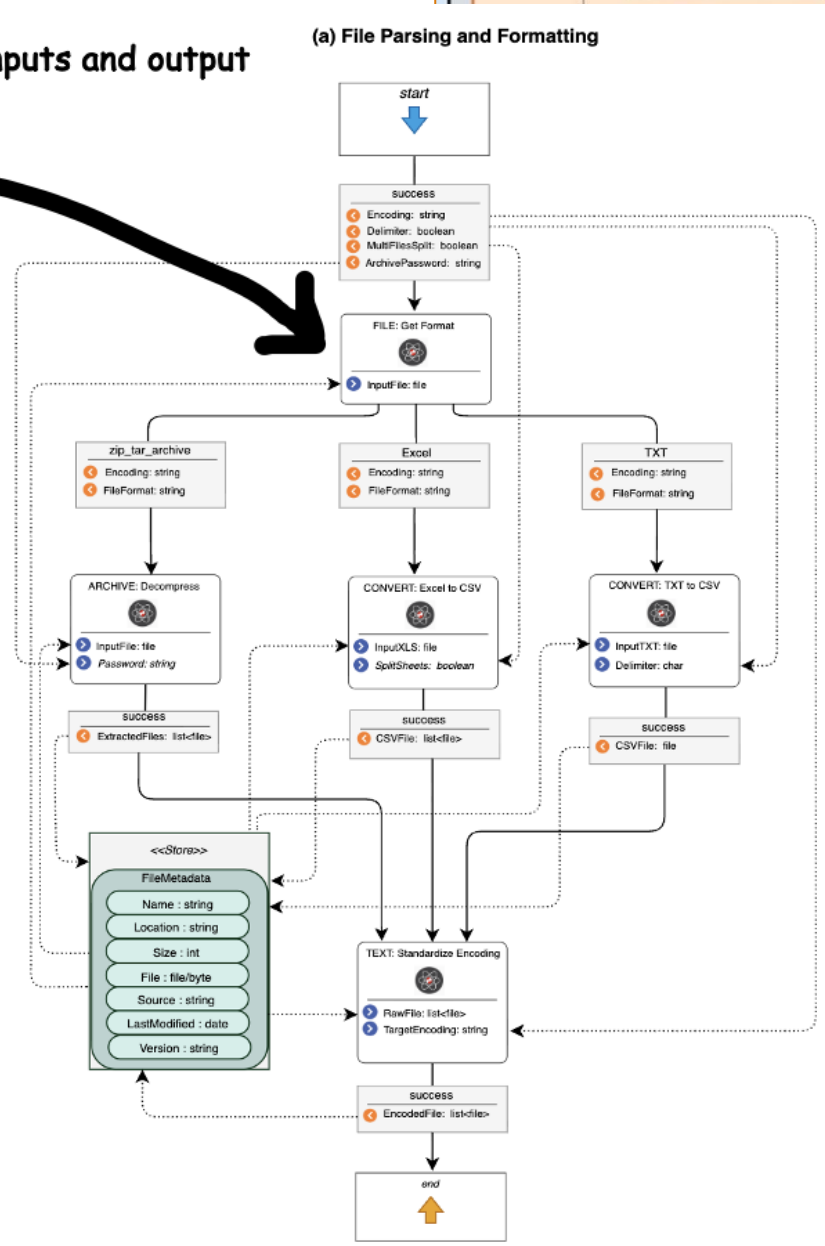


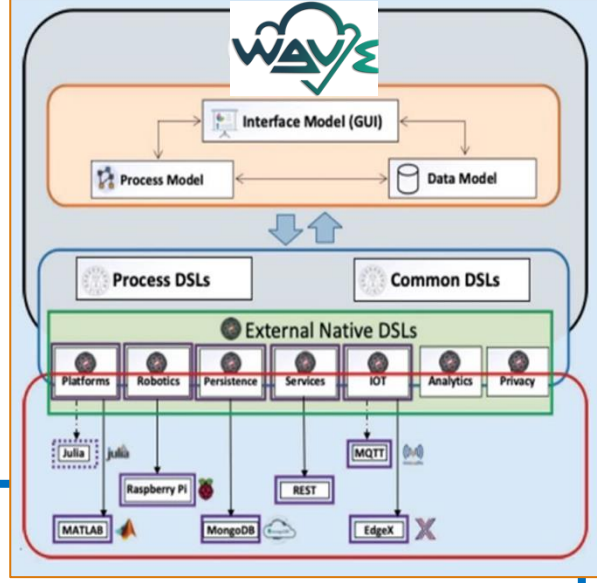
- Native
  - common.sibs
    - WORKSPACE: Init & Sync (Workspace (string) RemoteProvider (string) RemotePath (string) SyncStrategy (string)) --> |success (WorkingDirectory (string))|
    - FILE: Import from Dir (SourcePath (string) SourceFile (string) Wildcard (string)) --> |success (LocalFile (list<file>) FileInfo (FileMetaData))|
    - FILE: Get File Source (FileSource (enum[AWS, Local])) --> AWS | Local
    - FILE: Checksum Validator (InputFile (string) HashValue (string) Algorithm (string)) --> |success (ComputedHash (string) Checksum (boolean))|
    - FILE: Get Format (InputFile (string)) --> zip_tar_archive (FileFormat (string) Encoding (string)) | Excel (FileFormat(string) Encoding (string)) | Txt (FileFormat (string) Encoding (string))|
    - ARCHIVE: Decompress (InputFile (file) Password(string)) --> |success (ExtractedFiles (list<files>)|
  - data_ingestion.sibs
  - parsing_and_formatting.sibs
    - CONVERT: Convert Excel to CSV (InputXLS (file) Splitsheets (boolean)) --> |success (CSVFile (file))|
    - CONVERT: Convert Txt to CSV (InputTxt (file) Delimiter (char)) --> |success (CSVFile (file))|
    - TXT: Standardise Encoding (RawFiles (list <files>) TargetEncoding (string)) --> |success (EncodedFiles (list<file>))|
  - arch_count.sibs
    - FILE: Read CSV (InputFilePath (string)) --> |success (ListOfDictionaries (list <dict>))|
    - Data: Filter Data (Data (list <dict>) ColumnName (array) Value (dict <string, any>)) --> |success (FilteredData (list<dict>))|
    - REQ: Query Neo4J for Arch Count (Data (list <dict>) ArchTypesCombination (array) URI (string) Username (string) Password (string) Query (string)) -> Buildings Matched (DataWithArchCount (list <dict>)) | No Buildings Matched (Message (string))
    - FILE: Write CSV (OutputFilePath (string) Data (list <dict>)) --> |success (CSVFile (file))|



Connect the inputs and output branches

Double-Click to get SIB representation





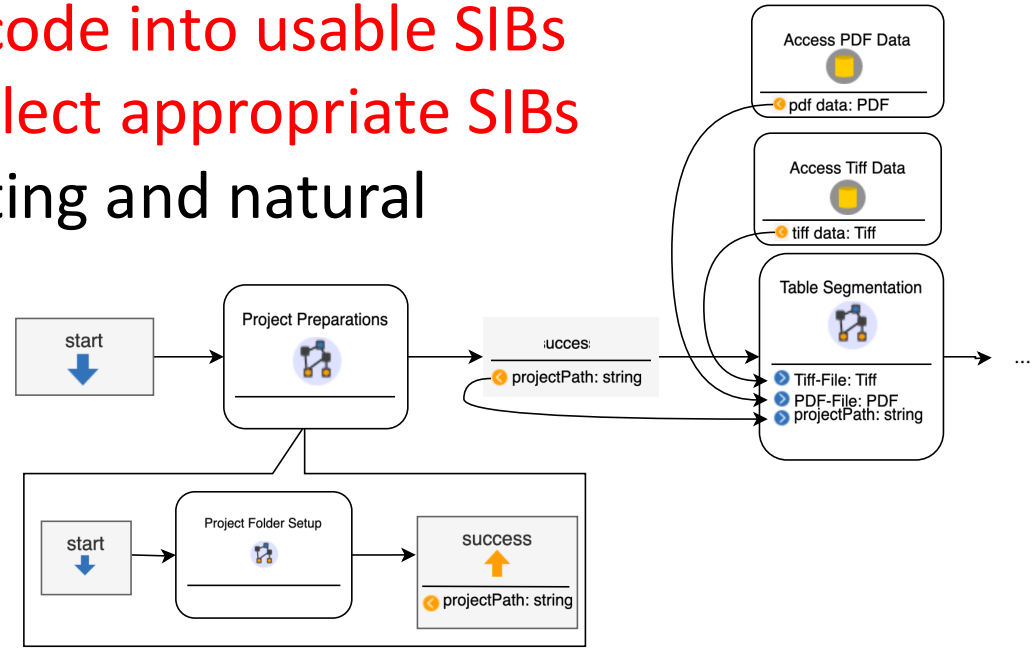
SLG Palettes (workflows)
AD-DSLs

Energy management

- Native
  - *common.slgs*
    - Data Ingestion (HashAlgorithm (string) ExpectedHash (string) LocalFilePath (array[SourcePath, SourceFile, Wildcard]) S3ConnectionStr (array) WorkspaceName (string) FileSource (enum[AWS, Local])) --> |success (ComputedHash (string) Checksum (boolean))|
    - File Parsing and Formatting (Encoding (string) Delimiter (boolean) MultiFileSplit (boolean) ArchivePassword (string)) --> |success (EncodedFile (list <file>))|
  - *arch_count.slgs*
    - Calculate Arch Count (InputFilePath(string) ColumnName (array) Value (dict<string, any>) ArchTypesCombinations(array) Neo4JURI (string) Username (string) Password (string) Query (string) OutputFilePath (string)) --> success (CSVFile (file) | No Buildings Matched (Message (string))

AI/ML and LC/NC:

- Structured outputs can be leveraged for visual suggestions, but that requires appropriate tooling support
- Natural-language editing of models looks promising
- Visual representation makes it easier for the human-in-the-loop to refine their prompts and validate the output
- LLMs can be leveraged to help transforming code into usable SIBs
- LLMs can help refine the workflow, RAG to select appropriate SIBs
- Combination of the accessibility of visual editing and natural language to empower non-experts



Service Centered Continuous Engineering Ingredients

+ AI

Use AI to

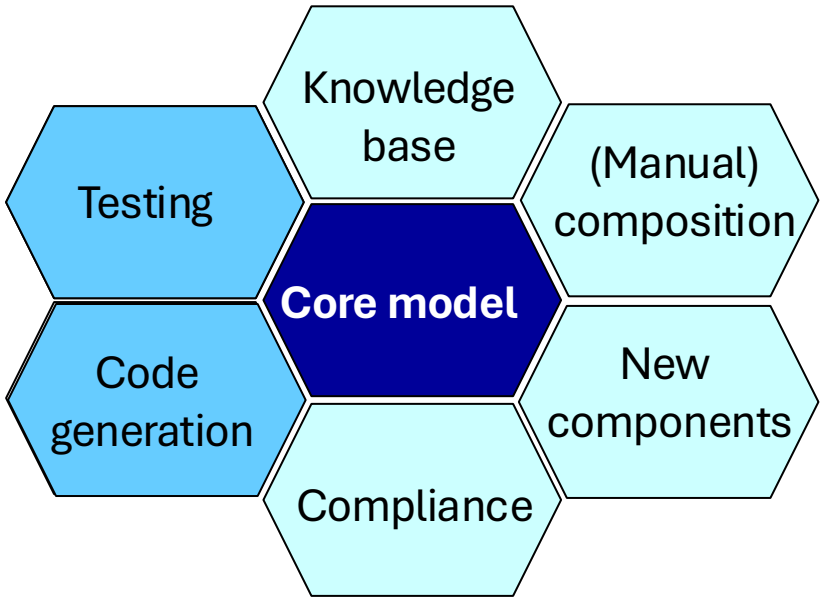
- Extract properties
- Support integration (make SIBs)
- Synthesize the logic
- Translate to a different target language/runtime

AI/ML itself as a domain

- AI's as SIBs
- Models as SIBs

Models

- formal (mathematical)
- properties
- model checking
- transformation (to code)
- model extraction



Genesys

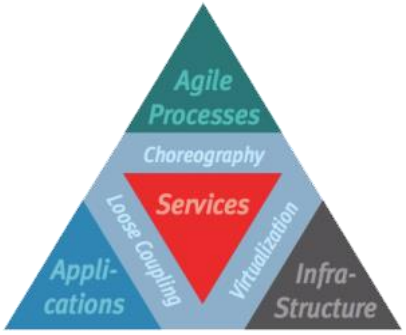
- model-to-model and model-to-code transformation

ITE

- model-based automated testing environment

LearnLib

- model inference by active automata learning



How to leverage your FMs and AIs in this context?

Use AI to

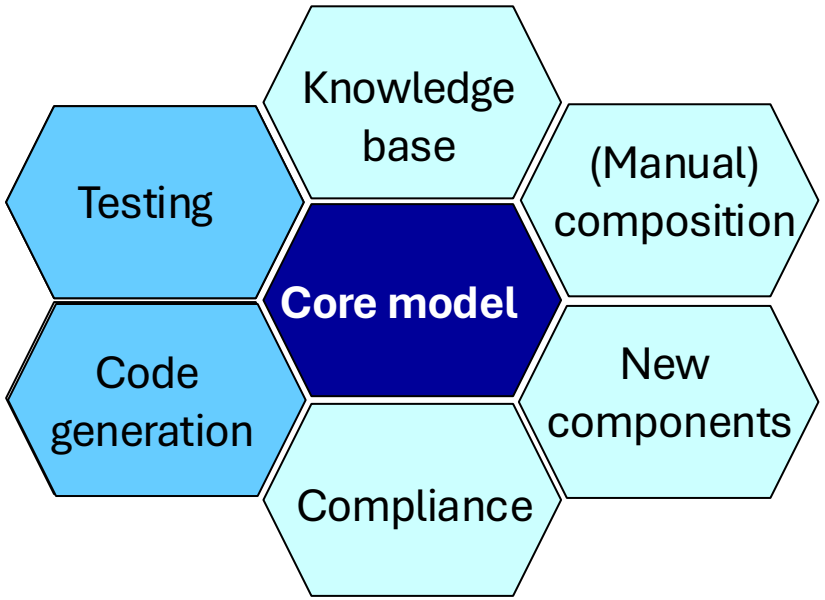
- Extract properties
- Support integration (make SIBs)
- Synthesize the logic
- Translate to a different target language/runtime

AI/ML itself as a domain

- AI's as SIBs
- Models as SIBs

Models

- formal (mathematical)
- properties
- model checking
- transformation (to code)
- model extraction



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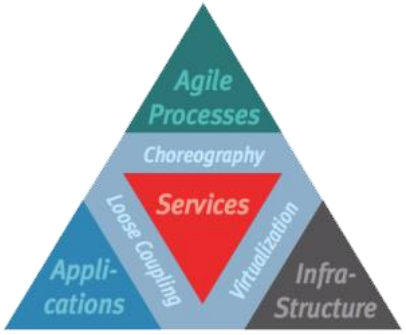

Taighde Éireann
Research Ireland

LArc workshop
(ICSE, Rio)

LCNC track
(ISoLA, Kos)

LC/NC platforms and AI: which future?

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WAVE
CRT·AI
I-Form
Advanced Manufacturing Research Centre
LERO
Software for a better world
University of Limerick
Health Research Institute
GREATLEAP