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Industrial Internet of Thingsを考える
～SoSとCyber Physical Systems～

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本日のお話の内容

- ▶ SoS (System of Systems) とは？何が問題なのか？
 - ▶ Industrial Internet Reference Architecture とCPS (Cyber Physical Systems)
- ▶ UAF (Unified Architecture Framework)
 - ▶ IoTによって複雑に複数のシステムが連携するCyber Physical System などのSystem of Systems (SoS) 中での、設計、実装の対象となる下位レベルまで一貫性のあるアーキテクチャの構築
 - ▶ <https://www.omg.org/spec/UAF/About-UAF/>
- ▶ 「IIoT ビジネス戦略と変革」のUAFへのマッピング

System of Systems (SoS)とは？

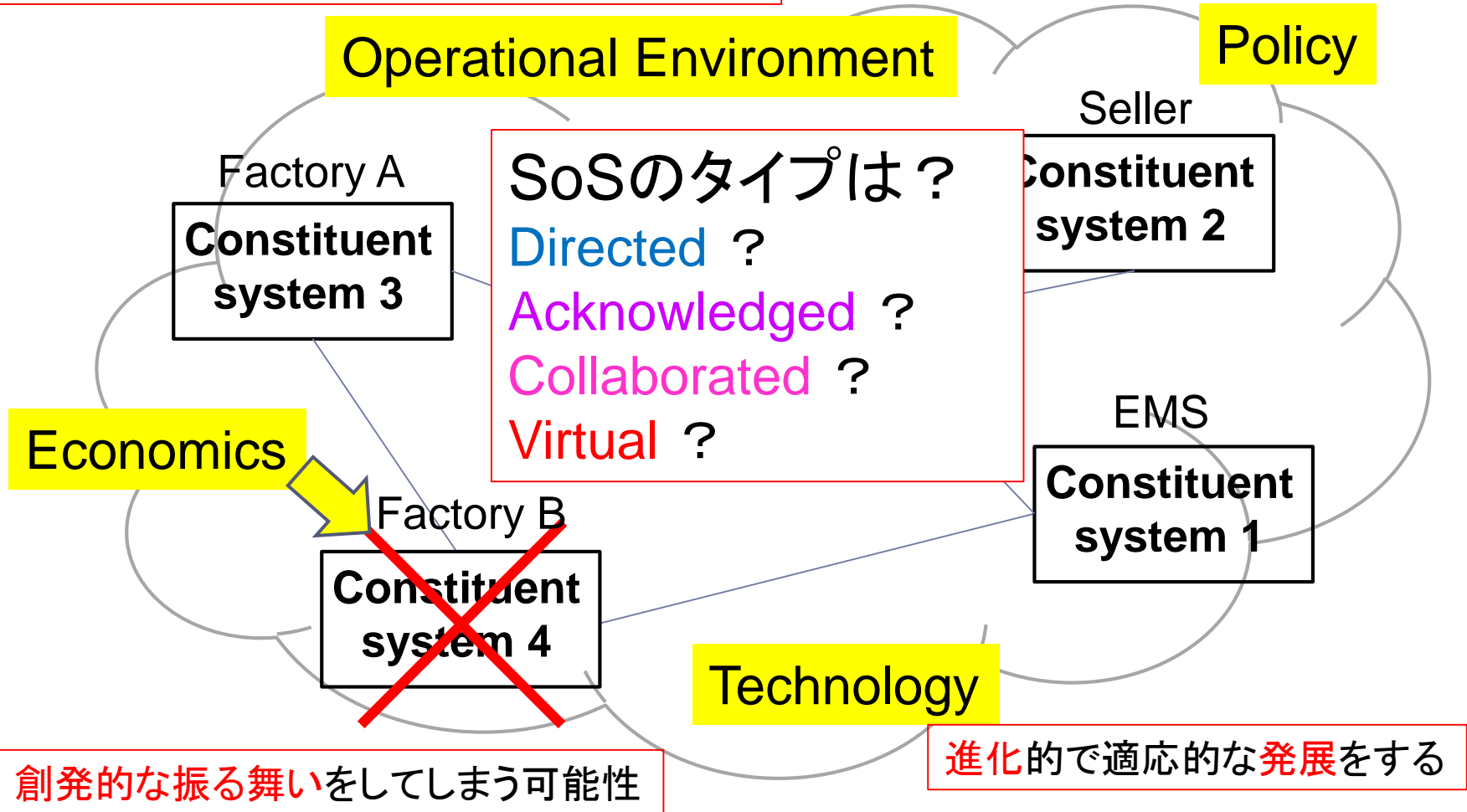
- ▶ 異質な個々のシステムが独立して動作可能ではあるが、ある共通したゴールに向けて共にネットワークされている大規模な統合された複数システムを**System of Systems (SoS)**と呼ぶ。
- ▶ SoSでは、その要素である構成システムは独立して動作可能であるが、それぞれ**異なるシステムライフサイクル**を持つ。
- ▶ 個々のシステムを最適化しても**SoS全体の最適性**は保証されない。

Mohammad, Jamshidi., ed. System of systems engineering: innovations for the twenty-first century. John Wiley & Sons, 2011

Maier, Mark W. Architecting principles for systems-of-systems. Systems Engineering., Volume1, Issue4 (1998), p.267-284.

System of Systems - It's a connected world!

個々の構成システムの運用・管理の独立性



SoSの分類

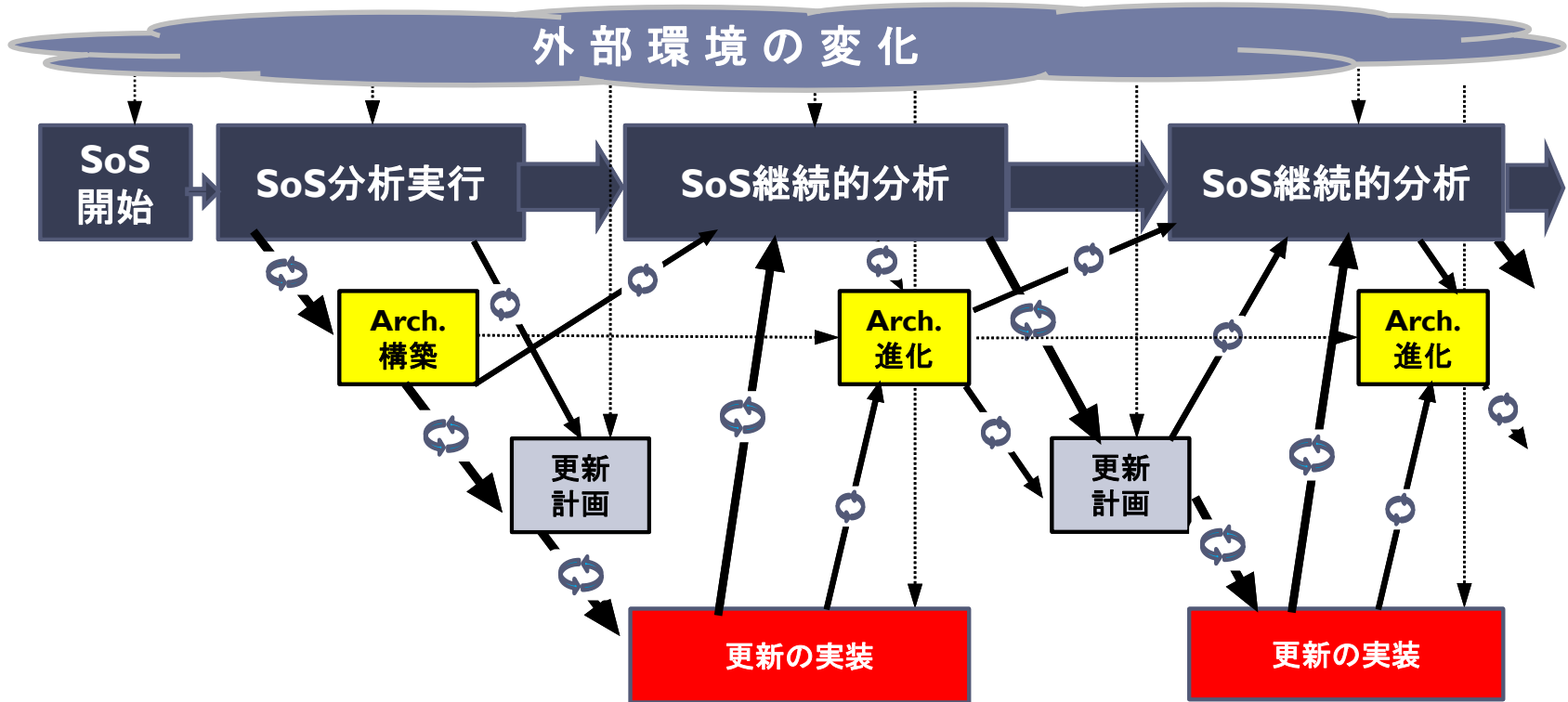
- ▶ **Directed** system of systems
 - ▶ 特定の目的を満たすためにつくられ、マネジメントされるSoSで、その構成システムはSoSに対して従属している。
- ▶ **Acknowledged** system of systems
 - ▶ 認識された目標、指定されたマネージャ、そしてSoSに対するリソースをもつSoS。
- ▶ **Collaborated** system of systems
 - ▶ 合意された中心となる目的を達成するために、コンポーネントシステムが多かれ少なかれ自発的に相互作用するSoS
- ▶ **Virtual** system of systems
 - ▶ 中央の管理権限およびSoSに関する中心的に合意された目的の欠けたSoS

SoSの課題

- ▶ どのようにSoSをモデル化し、シミュレーションするのか？
- ▶ SoSの構成システム間のインタフェースをどう扱うのか？
- ▶ SoSの創発的な振る舞いにどのように対処するのか？
- ▶ SoSの動的な境界にどのように対処するのか？
- ▶ 時間が経つにつれてSoSに関して進展する要求をどのように扱うのか？
- ▶ SoSエンジニアリングをどのように行うか？

Dahmann, Judith; Rebovich, George; Lowry, Ralph; Lane, JoAnn; Baldwin, Kristen. An implementers' view of systems engineering for systems of systems. Systems Conference (SysCon), 2011 IEEE International (2011), p. 212-217

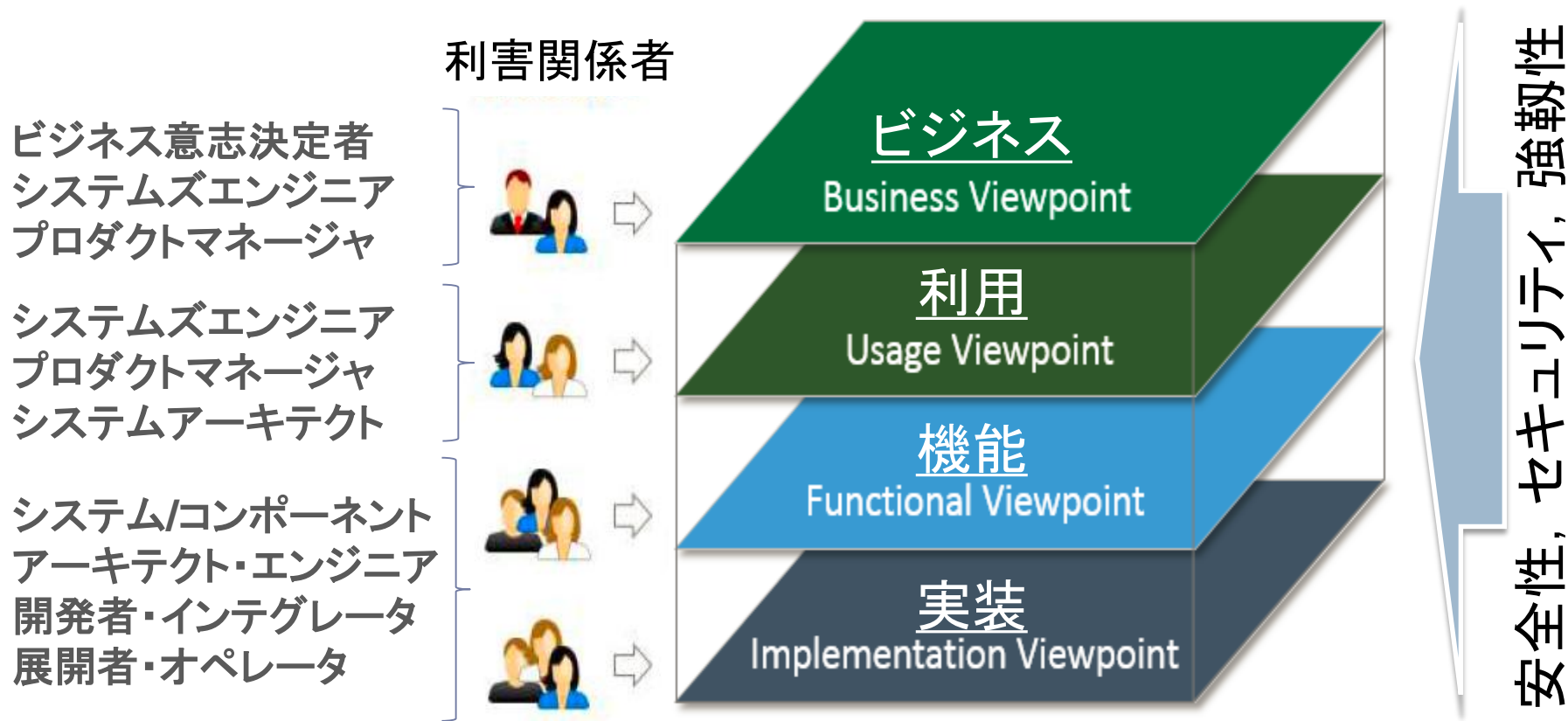
SoSマネジメントの考え方 Wave Model

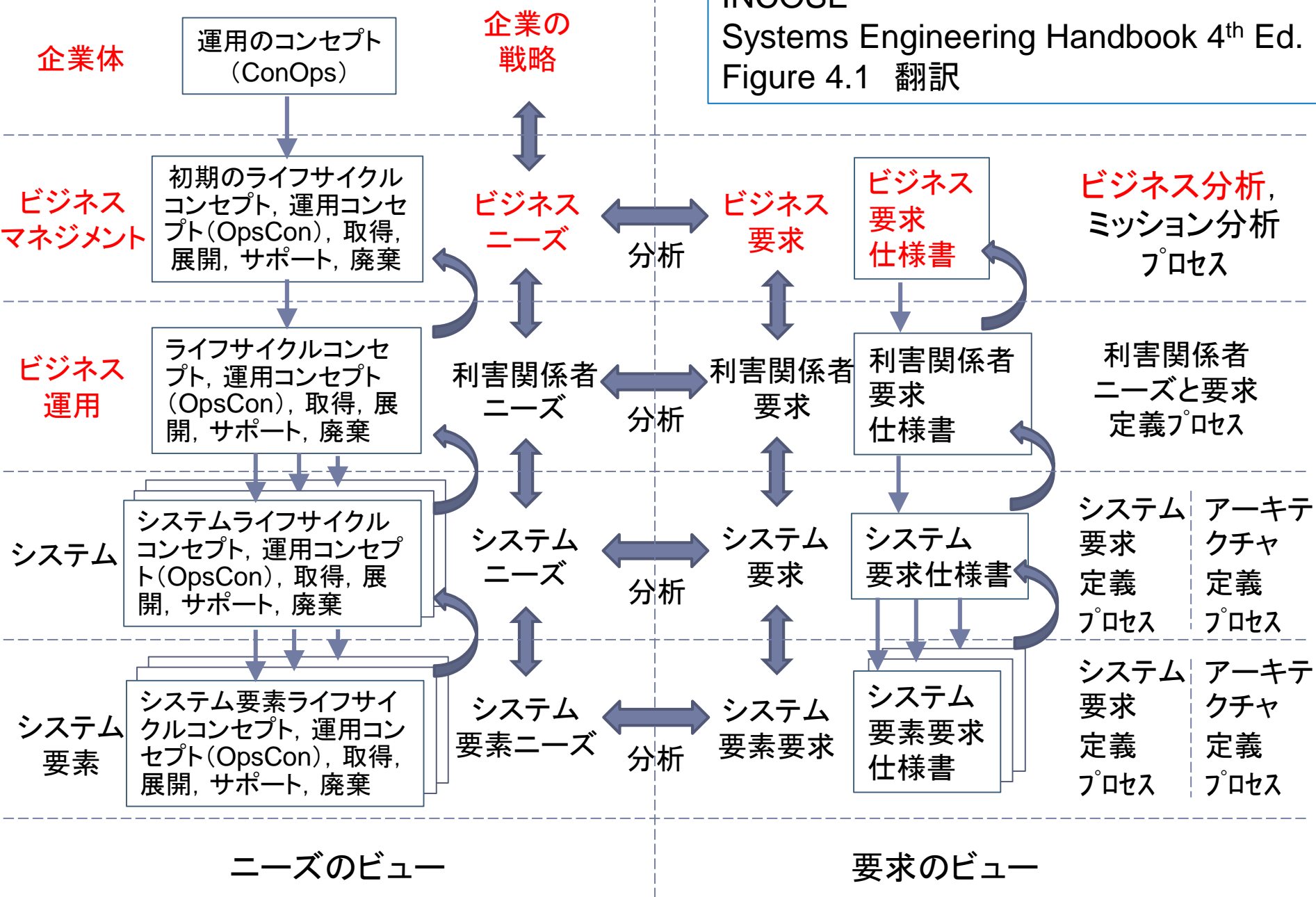


Dahmann, Judith; Rebovich, George; Lowry, Ralph; Lane, JoAnn; Baldwin, Kristen. An implementers' view of systems engineering for systems of systems. Systems Conference (SysCon), 2011 IEEE International (2011), p. 212-217

Industrial Internet Reference Architecture (IIRA)

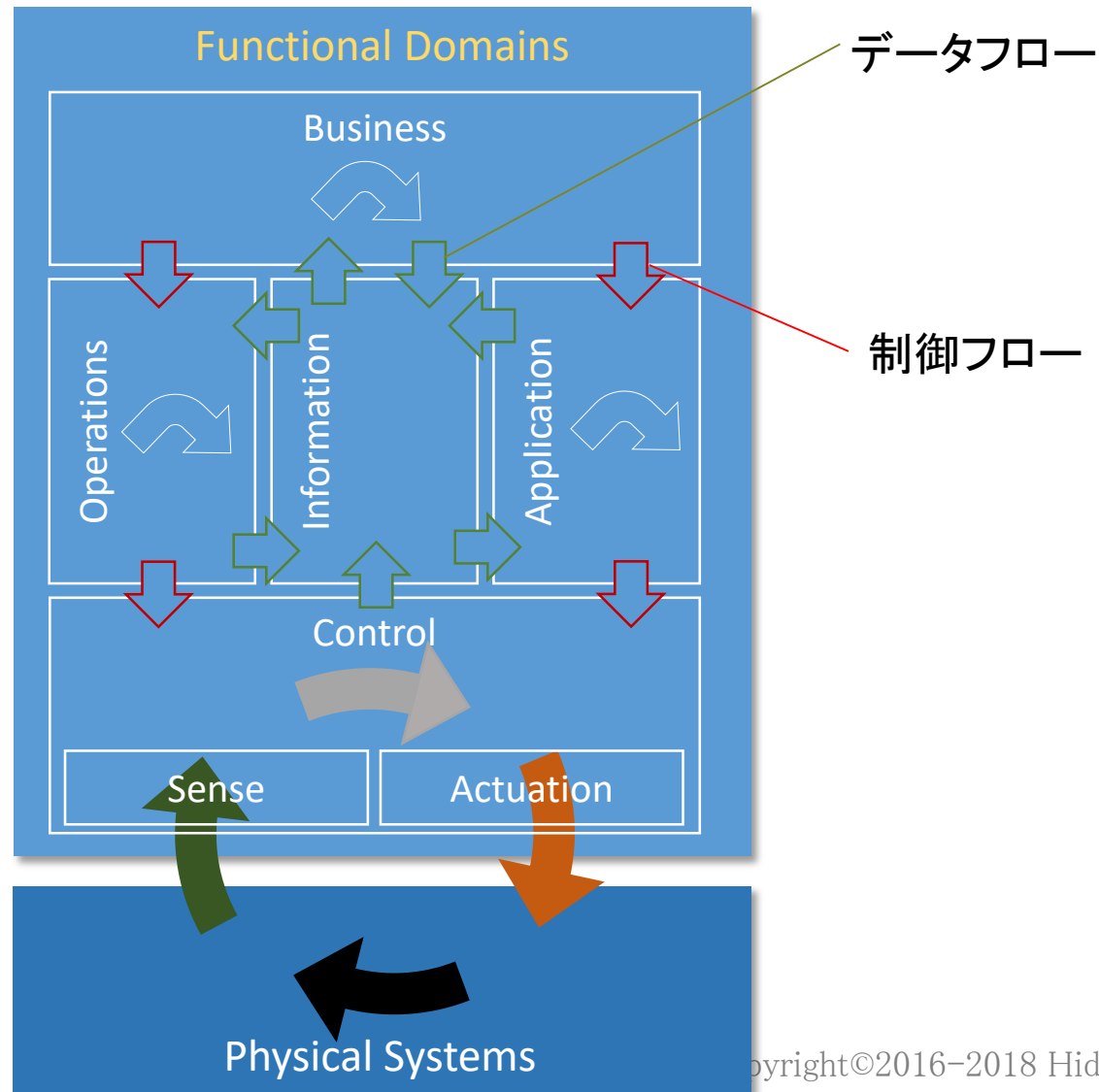
▶ 利害関係者の関心をフレームする「ビューポイント」





5つの機能ドメイン

- ▶ ビジネス
- ▶ 運用
- ▶ 情報
- ▶ 応用
- ▶ 制御



Cyber Physical System Functional Domains

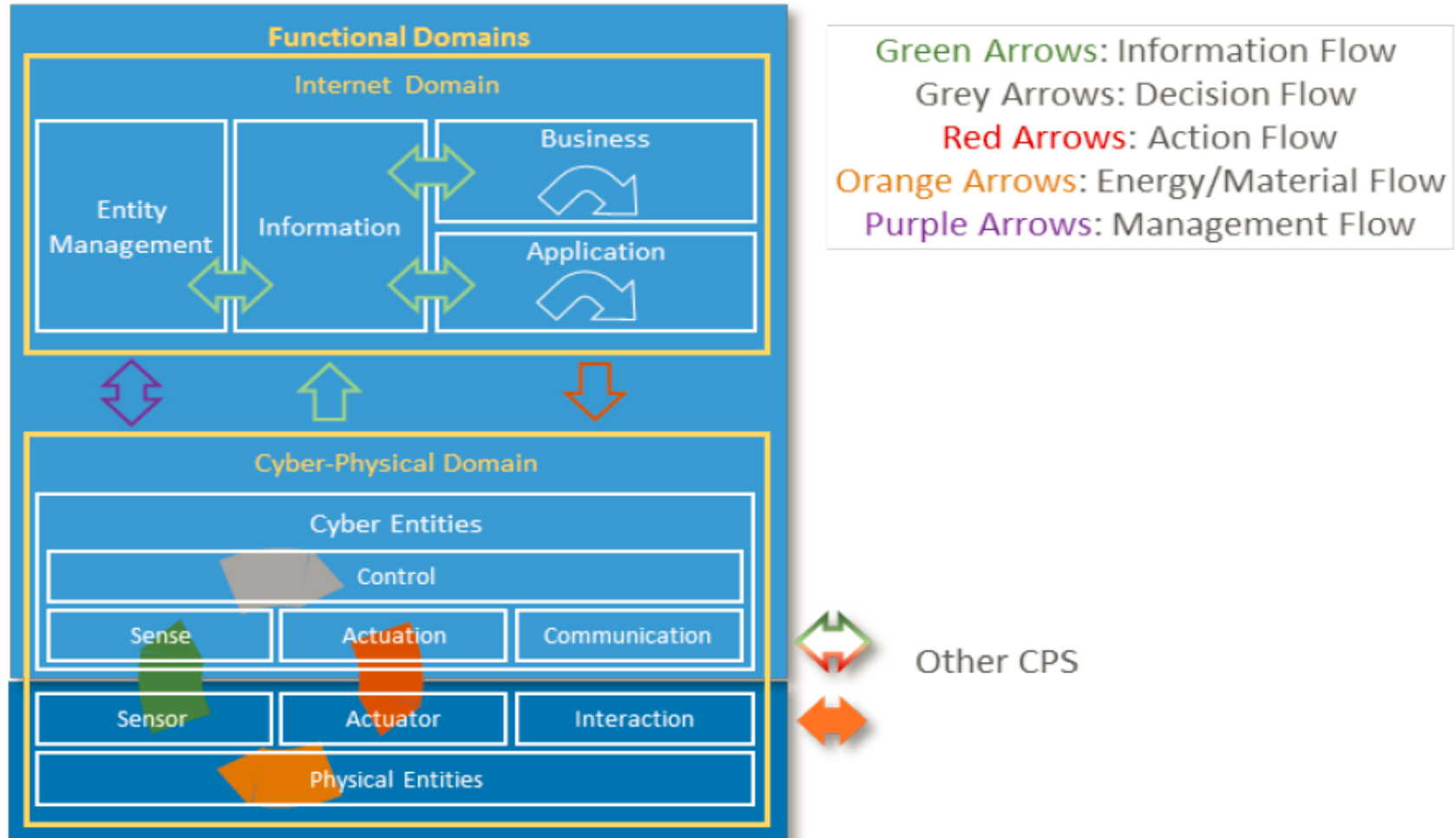


Figure 10: CPS Functional Domains

UAF Grid

	Taxonomy	Structure	Connectivity	Processes	States	Interaction Scenarios	Information	Parameters	Constraints	Roadmap	Traceability			
Strategy	Strategic Taxonomy	Strategic Structure	Strategic Connectivity				Conceptual Data Model	Measurements		Strategic Deployment Strategic Phasing	Strategic Traceability			
Operations	Operational Taxonomy	Operational Structure	Operational Connectivity	Operational Processes	Operational States	Operational Interaction Scenarios				Operational Constraints				
Services	Service Taxonomy	Service Structure	Service Connectivity	Service Processes	Service States	Service Interaction Scenarios				Service Constraints	Service Roadmap	Service Traceability		
Personnel	Personnel Taxonomy	Personnel Structure	Personnel Connectivity		Personnel States				Logical Data Model Physical schema	Measurements	Personnel Roadmap			
Resources	Resource Taxonomy	Resource Structure	Resource Connectivity	Resource Processes	Resource States	Resource Interaction Scenarios						Resource Constraints	Resource evolution Resource forecast	Resource Traceability
Security	Security Taxonomy	Security Structure		Security Processes								Security Constraints		
Projects	Project Taxonomy	Project Structure	Project Connectivity										Project Roadmap	Project Traceability
Standards	Standard Taxonomy	Standards Structure											Standards Roadmap	Standards Traceability
Actuals Resources		Actual Resources Structure	Actual Resources Connectivity											
Actuals Resources	Dictionary													
Actuals Resources	Summary & Overview													
Actuals Resources	Requirements													

<https://docs.nomagic.com/display/UPDM3P184/What%27s+New+to+UPDM+3+in+18.4>

UAF Grid

	Taxonomy	Structure	Connectivity	Processes	States	Interaction Scenarios	Information	Parameters	Constraints	Roadmap	Traceability
Strategy	Strategic Taxonomy	Strategic Structure	Strategic Connectivity							Strategic Deployment	Strategic Traceability
Operations	Operational Taxonomy										
Services	Service Taxonomy										
Personnel	Personnel Taxonomy										
Resources	Resource Taxonomy										
Security	Security Taxonomy										
Projects	Project Taxonomy										
Standards	Standard Taxonomy										
Actuals Resources											
Actuals Resources											
	Requirements										

horizontal rows: showing how the various viewpoints correspond to the generic layers of abstraction or domains

行: 抽象概念またはドメインの一般的な層に対応する様々なビューポイント

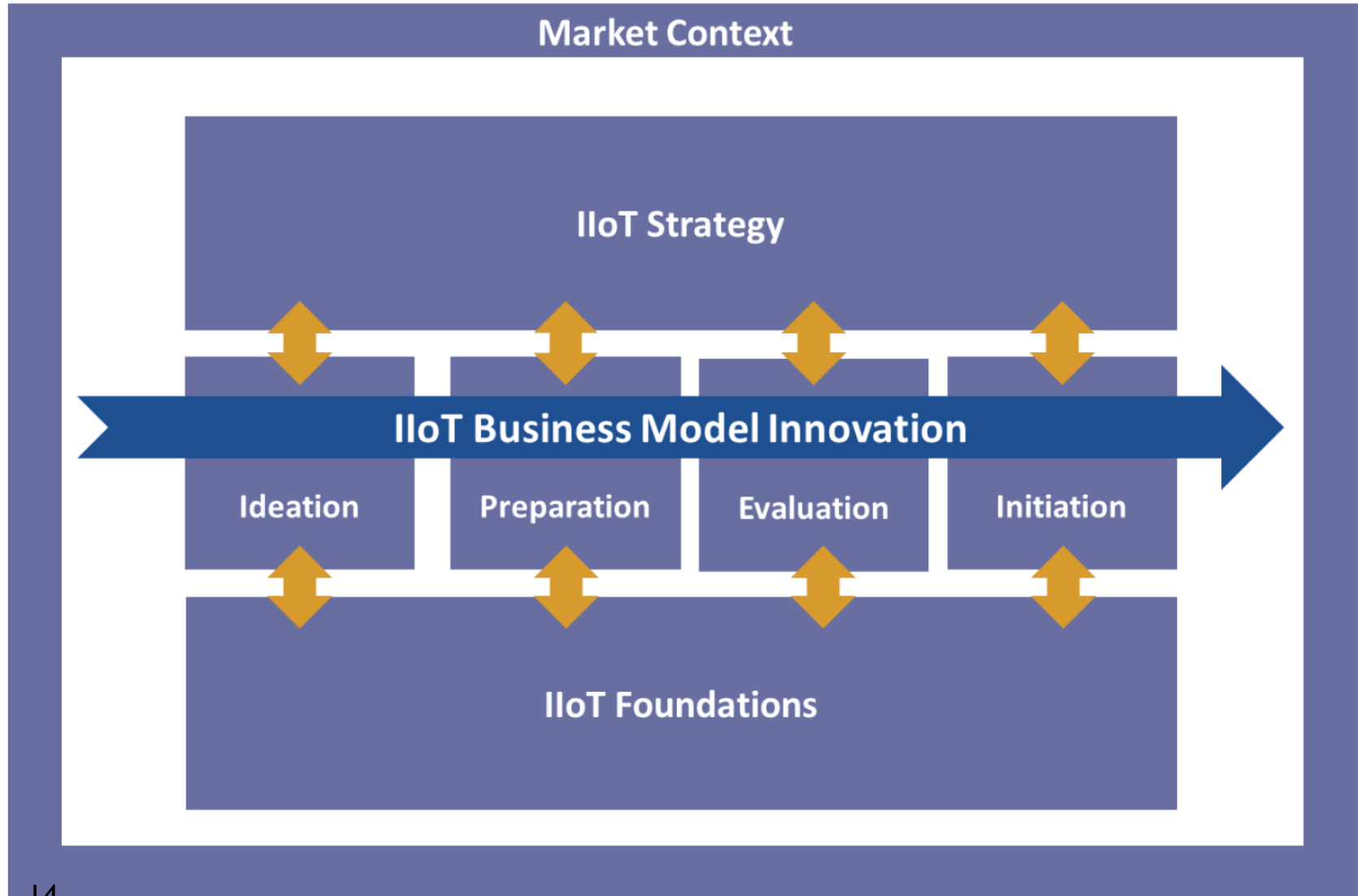
the columns: the types of model kinds or architectural representations used to describe the viewpoints.

列: ビューポイントを記述するために用いられるモデルの種類またはアーキテクチャ表現の型

UAF GridのIIRAとの関係

	Taxonomy	Structure	Connectivity	Processes	States	Interaction Scenarios	Information	Parameters	Constraints	Roadmap	Traceability			
Strategy	Business view						Conceptual Data Model	Measurements	Strategic Deployment	Strategic Phasing	Strategic Traceability			
Operations	Usage view			Operational activity	Operational Processes	Operational States			Operational Interaction Scenarios	Operational Constraints				
Services	Functional view				Service rocesses	Service States			Service Interaction Scenarios	Service Constraints	Service Roadmap	Service Traceability		
Personnel	Personnel Taxonomy	Personnel Structure	Personnel Connectivity		Personnel States				Logical Data Model Physical schema	Personnel Roadmap				
Resources	Implementation view									Resource States	Resource Interaction Scenarios	Resource Constraints	Resource evolution Resource forecast	Resource Traceability
Security	Security Taxonomy	Security Structure		Security Processes						Security Constraints				
Projects	Project Taxonomy	Project Structure	Project Connectivity								Project Roadmap	Project Traceability		
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Actuals Resources							Requirements							

IIC framework for identification and development of IIoT solutions



IIC framework for identification and development of IIoT solutions

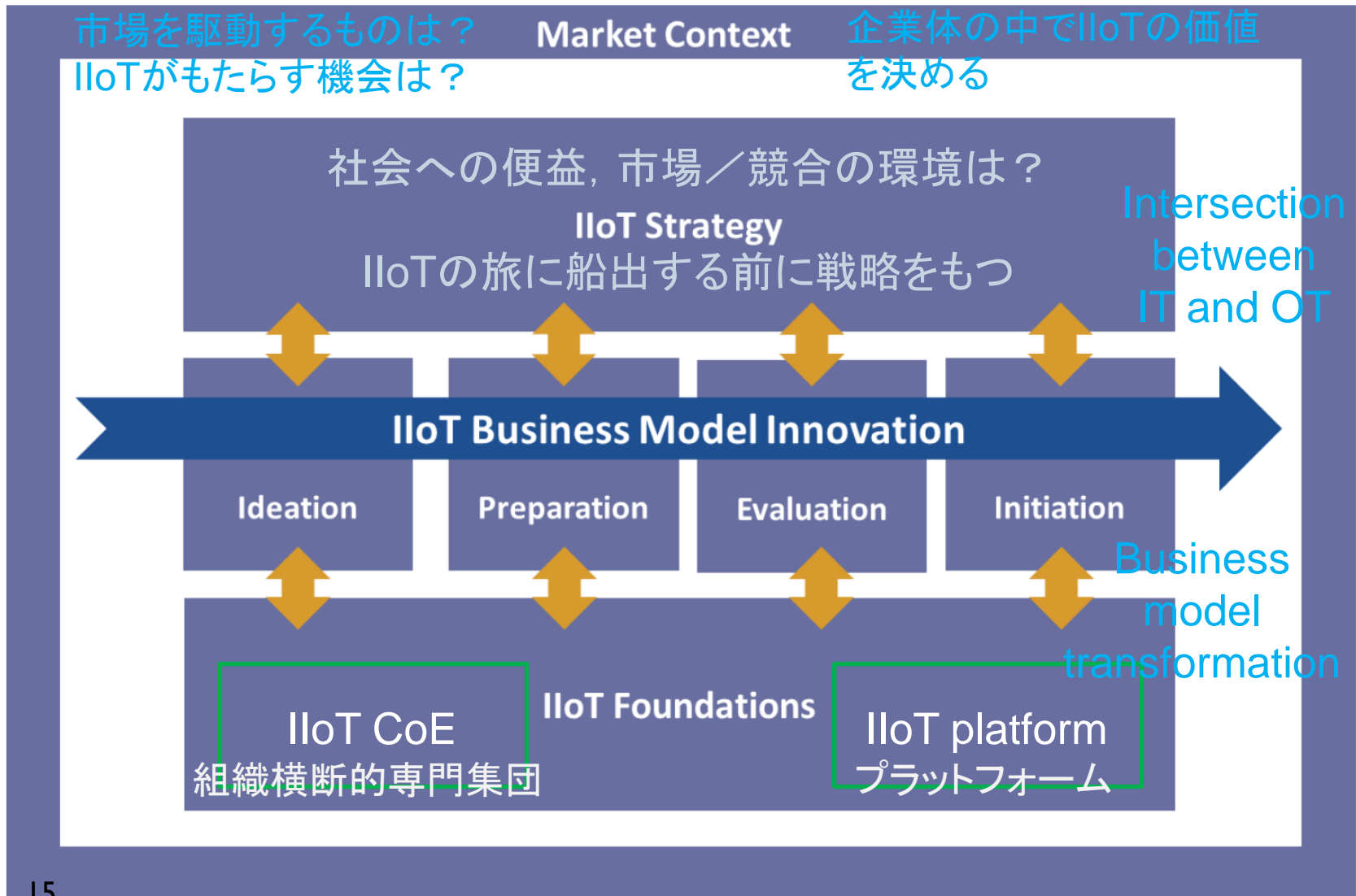


Figure 2-1: IIC framework for identification and deployment of IIoT solutions

Market Context

市場を駆動するものは？
IIoTがもたらす機会は？

企業体の中でIIoTの価値を決める

	Taxonomy	Structure	Connectivity	Processes	States	Interaction Scenarios	Information	Parameters	Constraints	Roadmap	Traceability			
Strategy	Strategic Taxonomy	Strategic Structure	Strategic Connectivity				Conceptual Data Model	Measurements		Strategic Deployment Strategic Phasing	Strategic Traceability			
Operations	Operational Taxonomy	Operational Structure	Operational Connectivity	Operational Processes	Operational States	Operational Interaction Scenarios				Operational Constraints				
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Industrial IoT Strategy

IIoTの旅に船出する前に戦略をもつポートフォリオマネジメント＝予算，ロードマップ

	Taxonomy	Structure	Connectivity	Processes	States	Interaction Scenarios	Information	Parameters	Constraints	Roadmap	Traceability	
Strategy	Strategic Taxonomy	Strategic Structure	Strategic Connectivity				Conceptual Data Model Logical Data Model Physical schema	Measurements		Strategic Deployment Strategic Phasing	Strategic Traceability	
Operations	Operational Taxonomy	Operational Structure	Operational Connectivity	Operational Processes	Operational States	Operational Interaction Scenarios				Operational Constraints		
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Industrial IoT Business Model Innovation

社内→社外との繋がりによる価値の創出／提供，評価，組織

	Taxonomy	Structure	Connectivity	Processes	States	Interaction Scenarios	Information	Parameters	Constraints	Roadmap	Traceability			
Strategy	Strategic Taxonomy	Strategic Structure	Strategic Connectivity				Conceptual Data Model	Measurements		Strategic Deployment Strategic Phasing	Strategic Traceability			
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Industrial IoT Foundational Capabilities

Intersection between IT and OT

	Taxonomy	Structure	Connectivity	Processes	States	Interaction Scenarios	Information	Parameters	Constraints	Roadmap	Traceability			
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Business model transformation

<https://docs.nomagic.com/display/UPDM3P184/What%27s+New+to+UPDM+3+in+18.4>

6.1.6 IIoT Governance

3.2.2および3.3.2からのリンク

- ▶ 運用の目的とデータ
- ▶ 全体の事業戦略と市場の目的とデータ
- ▶ 企業内のLOBsの目的の規定
- ▶ 企業内の運用技術(OT), 情報技術(IT)およびIIoTの標準
- ▶ IIoT戦略と目的
- ▶ 内部プログラムの開発

3.2.2 UNIFICATION OF DISPARATE BUSINESS ELEMENTS

= ビジネス要素の一本化

3.3.2 HARNESSING OPPORTUNITIES AT THE IT/OT BOUNDARY

= IT/OTの境界を束ねる機会

- ▶ **Line of business (LOB)** is a general term which refers to a product or a set of related products that serve a particular customer transaction or business need. (https://en.wikipedia.org/wiki/Line_of_business)

IIoTを形づくるには

- ▶ 事業戦略をもつこと
 - ▶ 市場コンテキストの把握
 - ▶ IIoTの価値を見定めること
- ▶ ビジネスモデルの変換, ビジネスの変更管理
 - ▶ 価値の創出と提供, ビジネスモデルの評価, 組織すること
- ▶ 組織を横断する専門集団の構築
 - ▶ ガバナンスの必要性
- ▶ IIoTプラットフォームの構築
 - ▶ テストベッドの活用
 - ▶ クロスプラットフォームの相互運用性

おわりに

- ▶ SoS (System of Systems) として、CPS (Cyber Physical Systems) をいかにエンジニアリングし、マネジメントするのか？この点が今後重要な課題となる。Industrial Internet Systems を形づくるためには、事業戦略を確実に持ち、価値を定め、ガバナンスを持つ必要がある。
- ▶ UAF (Unified Architecture Framework) を活用することで、IoT によって複雑に複数のシステムが連携する Cyber Physical System などの System of Systems (SoS) の中で、設計、実装の対象となる下位レベルまで一貫性のあるアーキテクチャを構築できることが期待される。