Towards Generic Domain Reference Designation: How to learn from Smart Grid Interoperability

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Abstract. The generic Smart Grid Architecture Model SGAM can act as a reference designation system in order to describe smart grid (technical) use cases as well as business cases. After having been applied successfully in the M/490 mandate and various FP7 projects, first adaptations of the model in other domains and scopes have been tried out. In this overview technical report contribution, we conduct a brief survey of these adapted models and outline their core aspects. We discuss typical fallacies in applying the SGAM to other domains and then discuss the process of developing derived models in a proper way. We conclude that the approach used in SGAM for reference designation is a highly valuable one, but it is necessary to follow basic guidelines for successful adoption of derived models for other domains.This paper will be presented at the D-A-Ch 2015 as a poster.

Keywords: Smart Grid, Modeling, Interoperability, Assessment

1 The Origins of the SGAM Model and Basics

One of the key challenges resulting from the so-called Smart Grid vision is to handle complexity in the new distributed systems landscape. The Smart Grid, being a true System-of-Systems (cf. [1]), is a prime example for the immense complexity that emerges in any non-trivial distributed system [12]. The first step to address this challenge is to structure the overall domain for the heterogeneous experts to discuss about. In this context, the results of the European Standardization Mandate M/490 currently gain momentum, especially the Smart Grid Architecture Model (SGAM). The SGAM has been developed by members from CEN, CENELEC and ETSI and considers established domain models (e.g., from US NIST and IEC) as well as domain-independent architecture frameworks such as TOGAF [3], [4]. Furthermore, in terms of interoperability dimensions the Grid-Wise Architecture Council Interoperability Context Setting Framework (CSF) was adopted. As shown in Figure 1, the SGAM provides the means to express various domain-specific viewpoints on architecture models by the concepts of so called *Domains*, *Zones* and *Interoperability Layers*, which shall be briefly introduced in the following sections.

The remainder of this technical report is organized as follows. Based on the overview of the SGAM [10] and its origins, different variants and derivatives of the SGAM are introduced in a very brief way. The derivatives are described in terms of their scope, dimensions and application area. In Section 2, the re-use of existing methods is reflected and various issues will be raised. In the very focus of the discussion is the GWAC stack for interoperability [5] and applying the SGAM out of its original scope. The report concludes with an overview on future meaningful applications in a standards based tool-chain with various inputs from the authors.

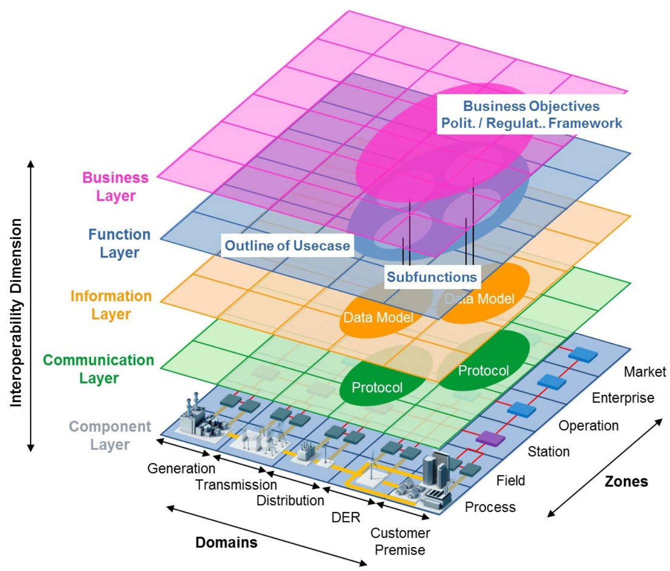

Fig. 1. Original SGAM model for reference designation of standards

1.1 The SGAM

The *Domains* regard the energy conversion chain and include: Generation (both conventional and renewable bulk generation capacities), transmission (infrastructure and organization for the transport of electricity across long distances), distribution (infrastructure and organization for the distribution of electricity to the customers), DERs (distributed energy resources connected to the distribution grid) and customer premises (both end users and producers of electricity, including industrial, commercial, and home facilities as well as generation in form of, e.g., PV conversion, electric vehicles storage, batteries, as well as micro turbines).

The hierarchy of power system management from the automation perspective is reflected within the SGAM by the following *Zones*: process (physical, chemical or spatial transformations of energy and the physical equipment directly involved), field (equipment to protect, control and monitor the process of the power system), station (areal aggregation level for field level), operation (power system control operation in the respective domain), enterprise (commercial and organizational processes, services and infrastructures for enterprises), and market (market operations possible along the energy conversion chain).

Finally, as it constitutes a major requirement towards distributed systems, the SGAM defines *Interoperability Layers* based on the GWAC IOP stack. These cover entities ranging from business objectives to physical components to express the respective architectural viewpoint. As proposed by TOGAF, interrelations between concepts from different layers shall ensure traceability between documented architecture properties.

One important aspect is the original scope of the SGAM model. Based on the work from the M/490 mandate, the original purpose was modeling the landscape of existing standards in order to find gaps for needed smart grids standards and show relations between existing work [6]. Previous work like the conceptual model from NIST had shown that, in order to distinguish between various aspects of Smart Grid solutions, more than one dimension had to be covered [7]. Based on the original scope, the SGAM can be considered only a reference designation system.

This concept is derived from the original physical hardware design process in order to allocate certain parts. As per definition, a reference designator unambiguously identifies a component in an electrical schematic or on a printed circuit board. The reference designator usually consists of one or two letters followed by a number, e.g. R13, C1002. The number is sometimes followed by a letter, indicating that components are grouped or matched with each other, e.g. R17A, R17B. The IEEE 315 series contains a list of Class Designation Letters to use for electrical and electronic assemblies. For example, the letter R is a reference prefix for the resistors of an assembly, C for capacitors, K for relays. Those schemes can be found in the power grid as well, e.g., in the IEC 61850 LN naming rules.

The ISO/TS 81346-10:2015 [8] contains sector-specific stipulations for structuring principles and reference designation rules on technical products and technical product documentation of power plant and therefore is applied within a lot of standards for finding MRIDs (Master Resource Identifier) with semantic background. It is applied in combination with IEC 813462, ISO/TS 813463, VGB-B 101 and VGB-B 102 for the classification of systems and objects, and for function-, product- and location-specific designation of technical products and their documentation for power plants. The SGAM can be seen as a higher-level concept with a three-dimensional visualisation on top of those designators. The three dimensions of function-, product- and location-specific can be re-visited in the SGAM in terms of the domains, zones and layers. In general, due to its component-based approach, the location of a system can be seen in the domains and zones, making it possibly to take a value-driven as well as an automation-driven point of view on an asset. As the Smart Grid solutions or composed on individual systems making the solution up from a technological portfolio, the product viewpoint can be derived from those layers. Individual communication stacks as well as communication technologies can be assessed for CAPEX and OPEX costs. For the functional viewpoint, the function layer directly does the job. Therefore, the experts agreeing on using the SGAM can discuss various viewpoints and align their view on a possible technical solutions.

1.2 The SCIAM

The Smart City Infrastructure Architecture Model (SCIAM) is one particular new derivative from the original SGAM model. First introduced and discussed in the German DIN/DKE Smart Grid Standardization roadmap (cf. [14]) for Smart Cities, it is a proposal based on the original success and model of the SGAM. Instead of the business layer, a so-called “action layer” is proposed but not yet agreed upon. As for domains and zones, new axes have been developed. The zones cover a mostly hierarchical way of structuring for physical locations.

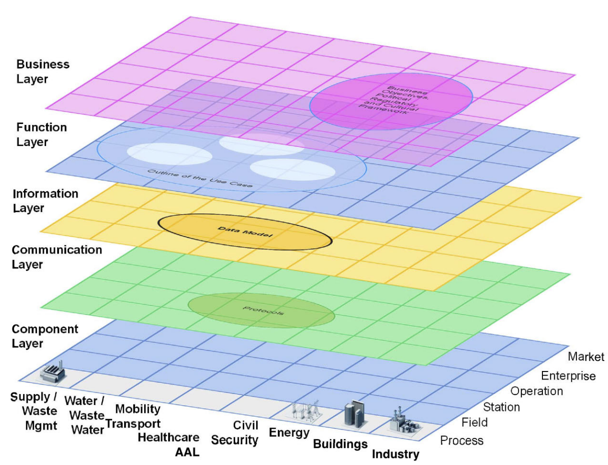

Fig. 2. Original SCIAM model for reference designation

Market, Enterprise, Operation, Station and Field as well as process from the Zones axis. This list can be considered a natural ordered list not being based on a bag principle. In addition to this, the domains consist of Supply /Waste Management, Water /Waste Water, Mobility and transport, Healthcare and AAL, Civil Security, Energy, Buildings as well as Industry. Based on this initial proposal, a model has been developed and brought to attention of IEC SEG1 [11] as well as the SSCC-CG (Smart and Sustainable Cities and Communities) at European level. Looking at the model, it is apparent that a different granularity than in the SGAM is needed as let alone the SGAM cube makes for only one lane (even only partly since we focus on electricity aspects) in the overall SCIAM scope. The group therefore has to develop a more high-level view on the use of the designation schema and limit themselves to focus on the convergence aspects of the individual domains in order to achieve synergies between them.

1.3 The EMAM

The Electric Mobility Architecture Model (EMAM) is one particular aspect which is currently being developed in the context of the so called IKT EM II (ICT for electric vehicles) program from the German ministry of economics and energy. As of now, it is mainly driven with the DKE toolchain process [3] in place, first emphasizing the need for a consolidated use case collection and than deriving actors and technical requirements from them which will provide the very basis of changing the granularity of the individual axis aspects.

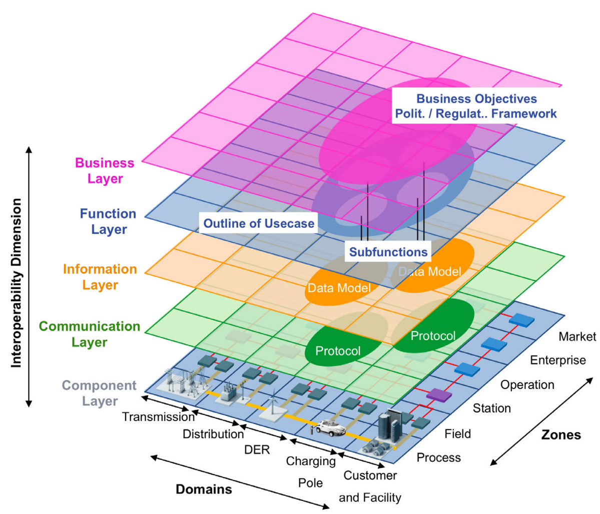

Fig. 3. Initial draft of EMAM model for reference designation

As [16] points out, re-using the SGAM in terms of modeling electric mobility is of interest. The focus shall provide a more detailed view on the electric distribution for the vehicle and the corresponding charging pole or charging station, make the EMAM zoom in instead of zooming out like the SCIAM. One drawback of SGAM in general is the point that only a snapshot of the current situation can be visualized. As the electric vehicle is moving, the zonal location can change based on the very context. Therefore, a disadvantage in terms of the object of interest being not properly located is healed and changed into an advantage for proper modeling. However, this model is still subject to change and input from the German IKT EM II model regions and the domain and zone structure must be discussed. It can, however, act as an example to change the SGAM to a much more focused granularity, trying to check if the modeling and reporting benefits still exist when doing so.

1.4 The HBAM

The concept of the Home and Building Architecture Model (HBAM) has been developed by the German DKE standardization body [15] within their scope to come up with a German Standardization Roadmap on Smart Home and Building. The current version is a working draft. The Interoperability Layers have been renamed to application, function, data model, interface and protocol and finally component. From the semantic point of view, this pretty much resembles the original model.

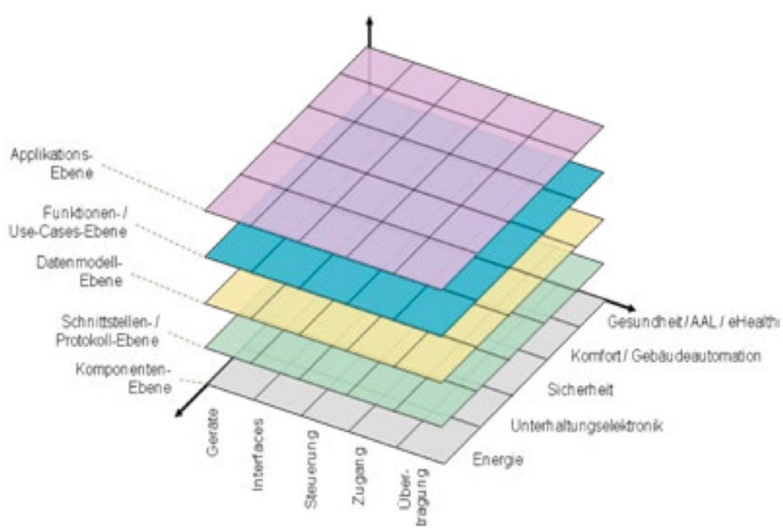

Fig. 4. Original HBAM model for reference designation

The zonal axis contains the eHealth, building automation, physical security, consumer electronics and energy domain. Therefore, just like with the SCIAM [11], more domains than one are addressed, but this time in the zonal area. The domain axis has been structured with the lanes of devices, interfaces, control, access and data exchange. Based on those early aspects, the national standardization body is still working on a new version of the model.

1.5 The RAMI 4.0

The Reference Architecture Model for Industry 4.0 (RAMI 4.0) is the most sophisticated derivative of the SGAM as of today, developed by ZVEI in Germany. Based on the German Industrie 4.0 concept, the main aspect is the re-use of the GWAC interoperability stack. In addition to business, function, information, communication and asset representing component, a new layer called integration is introduced. The domain and zone axis are not custom taxonomies but are based on the IEC 62890 value stream chain or the IEC 62264/61512 hierarchical levels, respectively.

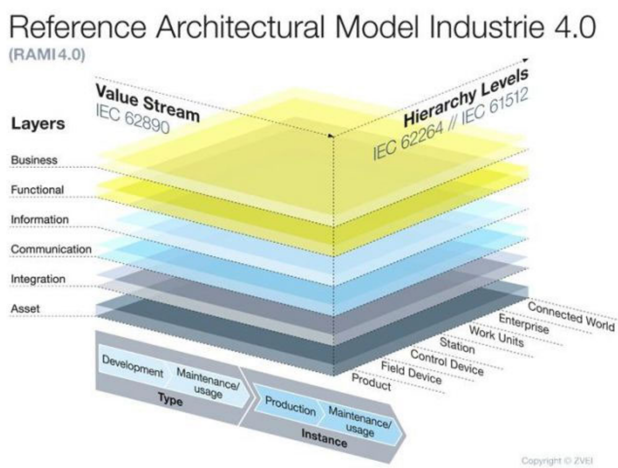

Fig. 5. Original RAMI 4.0 model for reference designation

The main purpose of the model is defined by ZVEI as follows: The model shall harmonize different user perspectives on the overall topic and provide a common understanding of the relations between individual components for Industrie 4.0 solutions. Different industrial branches like automation, engineering and process engineering have a common view on the overall systems landscape. The SGAM principle of having the main scope of locating standards is re-used in the RAMI paradigms, also using it as a reference designation system. The next steps for proceeding with the modelling paradigm is to come up with 101 examples for *Industrie 4.0* solutions in the RAMI, provide proper means for the devices to be identified and provide discovery service modeling for those devices, harmonize both syntax and semantics and focus on the main aspect of the integration layer which was introduced in order to properly model the communication requirements in factory automation.

1.6 A Summary of the Derivatives

Within this section we have presented the existing derivatives of the SGAM and their individual changes and new paradigms imposed. We looked at the new models from the point of view of using it as reference designation systems, mainly to distinguish between individual aspects of technical solutions and standards. The new models have mainly shown to change domain and zonal axis aspects and granularity of the existing SGAM. Within the next section of this technical report, we will discuss those changes and their implications more in depth.

2 Discussion on the Re-Use of Modeling paradigms

2.1 The GWAC Stack

One of the original aspects, also to align with the NIST work, was the use of a slightly compressed GridWise Architecture Council Interoperability stack for the SGAM. It covers various aspects of interoperability between systems on individual level. Figure 6 shows those adaptions made in order to lower the complexity within the SGAM. As this stack is also based on NEHTA Australian health-care models, re-using SGAM model paradigms shall also work with the more complex stack as well as in the health-care domain. If the stack can be

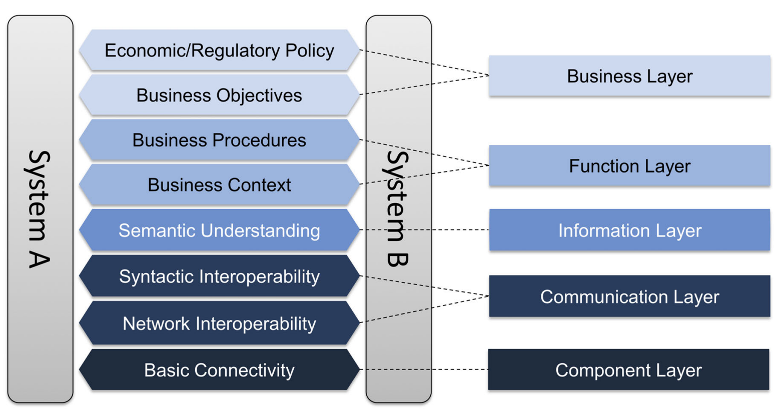

Fig. 6. Original GWAC stack in the context of SGAM

agreed upon, the main challenge for adoption is the change of the domain and zone axis as well as the needed modeling granularity. Certain methods to be used in context with SGAM only work if the bag principle is not applied. The aspect of the axis will be discussed in the next subsection.

2.2 Dimensions: Domains and Zones

One of the most important aspects of changing the SGAM towards a new or different domain is the proper application of defining a meaningful for the domain and zone axis. Domain and zone are normally defined from the reference designation point of view just like domain and range in the RDF standards. The domain typically covers the coarser granularity with less details and the zone implementation aspects for the individual organizations in scope with the overall model and how the act in the different domain facades. The next subsection discusses briefly what has to be focused on when defining domains and zones.

2.3 Existing Fallacies

The availability of a generic architecture model is, of course, highly desirable, as it provides a common frame of reference for a variety of systems. However, the experience with more domain-specific models shows, that there are some pitfalls in using architecture models [13]. In the following, some common misconceptions are summarized.

"Everything is a Reference Architecture" The term "reference architecture" has been used both excessively and erroneously in the community. It needs to be stated that the Smart Grid Architecture Model SGAM, as well as the other aforementioned models, are not "reference architectures". They are, as the name designates, architecture model that serve as a framework for reference designation. A reference architecture may and should be put into context of an architecture model, but this does not make the architecture model a reference architecture.

"Copy-and-Paste Approach" Applying an approach, which is successful in another domain, seems appealing at first glance, but often is taken too far. In many cases, features are "copied and pasted" from the source domain that do not fit the target domain. For a generic model, a clear process of domain abstraction needs to be introduced. As also seen in this paper, even the visualisations of the are not harmonized yet. This contribution relied on the original graphics.

"Silver Bullet Syndrome" Architecture models are useful and powerful concepts. Care needs to be taken not to overstretch the usefulness in an attempt to map each and every aspect of a system to the model, no matter how small and insignificant, or to use the model for concepts and processes for which there is no fit (such as purely operational concerns). The SGAM is a good example for this silver bullet syndrome. Evidently this architecture model was and is useful far beyond its originally intended scope (finding gaps in standardization,

see Section 2.4). However, recently, the SGAM has been mis-applied in tasks, for which it is plainly not suited, e.g., planning of types of physical network connections in smart grid demonstration projects. Of course, determining the extent of applicability is a learning process, and mis-application often contributes insights.

"Overloaded and Non-Contiguous Axis Entries" When deriving new models, it is sometimes tempting to fill up the three axes with all envisioned entries. This is often due to the fact that a four-dimensional model would be harder to handle. This approach often leads to two effects that are detrimental to the usability: (i) The axes are overloaded with too many entries, and (ii) the entries along the axes are organized in a non-contiguous manner, i.e., adjacent entries are not connected in a geographical, hierarchical or logical sense. In the original SGAM, the contiguity along each axis is an important factor in the usability of the model: the domains reflect the domains of energy generation, transmission and distribution in this order, the zones are reminiscent of the hierarchical SCADA pyramid ranging from a wide scope to a narrow scope, and the layers are organized from abstract business goals to concrete physical components. In derived models, this contiguity is often weakened or completely broken. For example, the zones of the SCIAM reflect a number of topics that are somehow related to smart cities, without the adjacent entries having any discernible (logical, hierarchical, geographical) relation to each other. For example, the field of "Healthcare/AAL" is located adjacent to the fields "Mobility/Transport" and "Civil Security", which are not in a strong relation to "Healthcare/AAL". This non-contiguous structure diminishes the expressiveness of the model and makes visualization, that works so well with the SGAM (systems can be visualized along the domains and zones axes as contiguous areas on each layer), a cumbersome effort in SCIAM: e.g., a multi-utility communication protocol that can be both used in the domains of "Water" and "Energy" cannot be visualized in the SCIAM in a straightforward manner, as these two domains are separated by three unrelated domains.

2.4 Application Out of Original Scope

As discussed before, the SGAM is not only transferred to different application domains, but also for the Smart grid, new scopes have been defined. One particular aspect in the integration of the SGAM with the IntelliGrid 62559 template in terms of UCMR applications [9], making documented use cases to be meaningful to be used in context with SGAM, re-using functions, actors and non-functional requirements [2]. In addition, tooling like the SGAM toolbox or EdFs Modsarus implemented in Sparx Enterprise Architect, visualing and manipulating SGAM graphical models to the individual needs is of highest interest as SGAM is used to communicate about Smart Grid solutions. Figure 7 provides an example where the SGAM model visualizer was converted to fit to map a RAMI 4.0 example, showing also the genericity of tooling to be applied in different domains.

In addition, as security is and additional cross-cutting issues heavily related to interoperability in general, integrating security standards and domain mod-

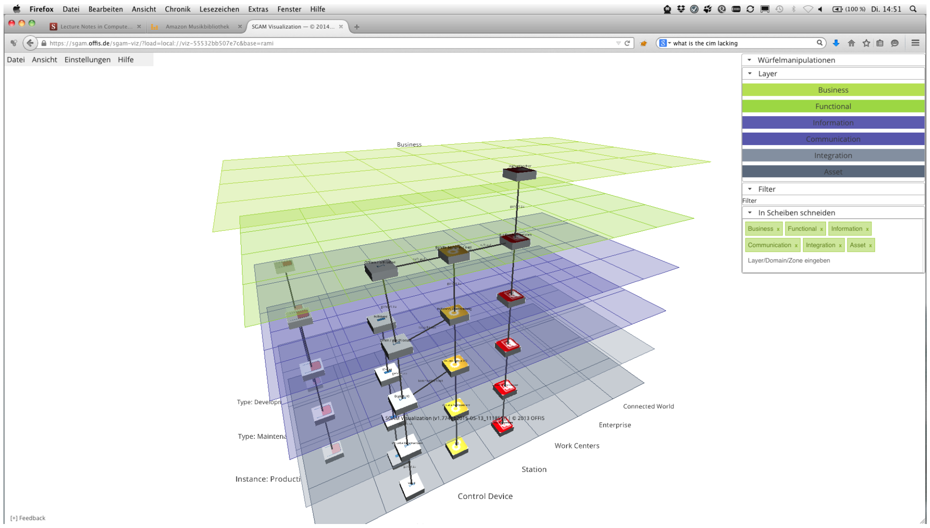

Fig. 7. RAMI 4.0 model 101 example from ZVEI in 3D Visualization

els like NISTIR 7628 into the designation system of SGAM has been worked on. New applications for SGAM will evolve over the time, as more and more experience is gained from projects applying the SGAM in day-to-day life. One particular aspect will be the modeling level and how much model-driven development can be based on SGAM models and if the model/method can be pushed down to requirements engineering level complementing technology and methods like SysML.

3 Conclusion and Future Work

To conclude this report, we have clearly shown that the SGAM model is, at least in the sense of standardization, a huge success for heterogeneous groups to discuss about infrastructure systems of systems. The authors have successfully applied the SGAM in various projects. We have also identified hidden fallacies or unintended design-paradigms when applying it. It has been adopted for various new purposes. This contribution summarizes our gained experience. However, it has become clear that certain basic paradigms shall be adhered to in order not to violate the original scope and produce unusable models which are often (wrongly) labeled as reference architectures. The SGAM shall be seen as a reference designation model. In addition to the original SGAM scope, new methods for Use case IEC 62559 integration, security analysis based on NISTIR 7628 as well as tooling chains have been developed. Future work like EMAM or using the model in a maritime context will have to cover those tools also for the derivative model under development.

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