DREAM Principles from the PORTAL-DOORS Project and NPDS Cyberinfrastructure*

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***Abstract*—The PORTAL-DOORS Project (PDP) has been pursued to develop the Nexus-PORTAL-DOORS-Scribe (NPDS) cyberinfrastructure as a distributed network system of data repositories to manage lexical and semantic data and metadata from and/or about online and offline resources. Designed with the *Hierarchically Distributed Mobile Metadata* (HDMM) architectural style in a manner analogous to IRIS-DNS, the NPDS cyberinfrastructure provides distributed multilevel metadata management as an open, flexible, and extensible networked system of independent community customizable *who-what-where* registries, directories, and diristries for identifying, describing, locating, and linking things on the internet, web and grid. In the current work reported here, we combined our original principles from PDP, HDMM, and NPDS together with additional principles for scientific reproducibility and social engineering related to our family of quantitative metrics with acronym FAIR for *Fair Attribution to Indexed Reports* and *Fair Acknowledgment of Information Records*. We call this new consolidated collection of principles the DREAM principles with acronym DREAM for the phrase *Discoverable Data with Reproducible Results for Equivalent Entities with Accessible Attributes and Manageable Metadata*. To codify these DREAM principles as a concrete artifact for the semantic web, and thus to operationalize their use, we developed an OWL 2.0 ontology that we named the PDP-DREAM ontology.**

***Index Terms*—Semantic web, PORTAL-DOORS project, DREAM principles, FAIR metrics, NPDS cyberinfrastructure, metadata management, data stewardship.**

I. Introduction

The semantic web has yet to realize the vision of the pervasive network of machine-understandable, interoperable repositories of knowledge which its founders envisioned [1]. Various transition barriers, including non-interoperable cybersilos and a dearth of easy-to-use tools and applications supported by adequate infrastructure have impeded the transformation of data on the lexical web to knowledge on the semantic web. In pursuit of this goal, PDP has developed the NPDS cyberinfrastructure for resource data and metadata publishing to serve as a bridge between the lexical and the semantic webs [2]–[4]. Based on the HDMM architectural style [5] in a manner analogous to IRIS-DNS [6] for the lexical web, PORTAL registries register labels and tags while DOORS directories publish resource locations and descriptions for the semantic web [2]. This original design with lexical PORTAL and semantic DOORS servers has since been enhanced to include Nexus diristries [7]–[9] and Scribe registrars [9], [10] in a network that we now call the NPDS cyberinfrastructure.

For continuing development of NPDS, PDP has adopted three guiding perspectives with views directed at software architecture, experimental science, and social engineering. The software architecture perspective refers to the original PDP software design principles [2] and HDMM architectural style [5] which govern the network and structure of the computational components of NPDS [9]. The experimental science perspective refers to the addition of the important principles of reproducibility and equivalence in science that led to the renaming of the PDP principles as the DREAM principles [11]. The social engineering perspective refers to the use of the FAIR metrics [12] as another new addition to NPDS [13] that PDP hopes will contribute to an improved environment for truthful scientific publishing free of various forms of plagiarism, not just the plagiarism of words, but also the plagiarism of ideas.

The *IEEE Publication Services and Products Board Operations Manual* defines five levels of plagiarism [14]. We describe here another kind of plagiarism called *idea laundering*, analogous to the concept and practice of money laundering, in which ideas are plagiarized and then the plagiarism is hidden in plain sight. To clarify this analogy, first define *money laundering* as the act of passing money that was illegitimately obtained through another illegitimate process with the intent of making it appear legitimate, ie, *making dirty money look clean*. Then define *idea laundering* as the act of passing ideas that were illegitimately obtained through another illegitimate process with the intent of making it appear legitimate, ie, *making dirty ideas look clean*.

As quantitative measures for detecting this plagiarism, the FAIR metrics [12] have been integrated into the NPDS cyberinfrastructure as embedded tools with a method by which to identify authors who fail to adhere to proper citation practices. In addition, a set of corresponding FAIR principles have been developed as a list of guidelines to promote good citation practices. These FAIR principles are related to the COPE principles [15] adopted by most reputable journals to encourage ethical practices in scholarly research publishing that prohibit the plagiarism of content including idea plagiarism.

Although we introduced the FAIR metrics with definitions and formulas [11], [12] and the DREAM principles with motivations and descriptions [11], [13] in other recent work, we have not yet specified and formalized the DREAM principles in detail as a new consolidated collection. Therefore, as novel contribution presented here, we codify the DREAM principles with a specification as a concrete software artifact for the semantic web in the form of an OWL 2.0 ontology that we have named the PDP-DREAM ontology. We discuss this PDP-

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Table I
SUMMARIZING PHRASES FOR THE DREAM PRINCIPLES AS THE FOUNDATION FOR THE PORTAL-DOORS PROJECT

Acronym	Main Phrase	Alternative Phrases			
D	Discoverable Data	Decentralized	Distributed	Democratized	Diristries
R	(with) Reproducible Results	Repositories	Records	Resources	(of) Reusable
E	(for) Equivalent Entities	(for) Enhanced	(for) Extensible	(for) Equivalent	Entity
A	(with) Accessible Attributes	Accessible	Accurate	Available	Attribute
M	(and) Manageable Metadata	Metadata	Metadata	Metadata	Metadata

DREAM ontology in the context of a partial review of PDP, NPDS, HDMM, and FAIR.

II. LEXICAL PORTAL REGISTRIES

Analogous to IRIS, lexical PORTAL registries publish resource entity labels and tags. PORTAL servers are established by independent communities which set local policies governing the registration of resources, ie., registries focused on particular problem areas: eg., ManRay [16], SOLOMON [17].

Comply with Root Schema and Specific Schema: "Adhere to the schema required by root servers of the generic PORTAL registry type" [2, pg. 197, Sec. VII-D, itm. 1]. "Adhere to the schema required by master servers of the same specific PORTAL registry" [2, pg. 197, Sec. VII-D, itm. 2]. PORTAL servers maintain the integrity of their problem oriented domains by applying concept validating methods [18] for the selection of records entered into their repositories (include/exclude) according to their community policies.

Recommend Related PORTAL Servers and DOORS Servers "Provide a list of recommended PORTAL master servers of different specific registry types" [2, pg. 197, Sec. VII-D, itm. 3]. "Provide a list of recommended DOORS primary servers to facilitate recursive forwarding" [2, pg. 197, Sec. VII-D, itm. 4]. PORTAL servers should provide a set of recommended PORTAL master servers with topical areas relevant to that of the server. PORTAL servers should also furnish a set of recommended DOORS servers to enable intercommunication between the set of DOORS servers which serve the recommended PORTAL servers.

Retrieve Resource Records "Perform a lookup of a registered resource by label or tag" [2, pg. 197, Sec. VII-D, itm. 5]. When resources on PORTAL servers are queried via label or tag, the associated primary and secondary DOORS servers can be returned for their corresponding records with location and description metadata for the same identified resource.

Publish Resource Cross-References and Owner "Perform a lookup of a registered resource by label or tag" [2, pg. 197-198, Sec. VII-D, itm. 6]. "Perform other standard requests of registrar/registry systems" [2, pg. 197-198, Sec. VII-D, itm. 7]. When resources on PORTAL servers are queried via label or tag, cross-references for resources in other systems can also be returned. Other methods by which to search for resources are also available, for example, a user may search for all resources by a certain owner.

III. SEMANTIC DOORS DIRECTORIES

Analogous to DNS, semantic DOORS directories publish locations and descriptions of resource entities in a format compatible with the semantic web. Therefore, DOORS directories should support text processing of records with semantic markup using formats equivalent to or interoperable with the XML/RDF/SPARQL semantic stack [19].

Map Labels to Locations: "Perform a lookup for a resource labeled uniquely by URI (or IRI) and return the associated URLs" [2, pg. 196, Sec. VII-C, itm. 1]. When performing a query for an entity uniquely labeled via a URI or IRI, the returned URLs or IDNs are required to be resolvable locations for the resource site, the owner's RDDL metadata, or the owner's contact information.

Map Tags to Locations: "Perform a lookup for a resource labeled uniquely by tag" [2, pg. 196, Sec. VII-C, itm. 2]. Users can lookup entities uniquely labeled with a tag via DOORS servers and obtain the URL(s) of the relevant resources.

Lexical String Search of Labels and Tags: "Find resources by string query of character substrings in labels or tags" [2, pg. 196, Sec. VII-C, itm. 3]. DOORS servers allow users to search for resources via character strings in the labels and tags.

Semantic SPARQL Search of Descriptions: "Find resources by semantic query with SPARQL of semantic statements in descriptions" [2, pg. 196, Sec. VII-C, itm. 4]. DOORS servers allow users to perform SPARQL queries over semantic descriptions of entities.

Provenance and Authentication: "Include the provenance and signature of each resource record returned" [2, pg. 197, Sec. VII-C, itm. 5]. For each lookup or query request performed, whether of semantic descriptions or of lexical labels, provide the provenance and unique signature of each record.

IV. NEXUS DIRISTRIES AND SCRIBE REGISTRARS

Nexus diristries (with the term diristry coined from DIRectory + regISTRY) [9] are designed to act as servers in which the functions of both PORTAL and DOORS servers can be implemented on the same network node. Operationally, Nexus diristries provide services consistent with the services of both PORTAL registries and DOORS directories. However, Nexus diristries allow these functions to operate on the same physical server at the same network node. This alternative implementation with the combination of PORTAL and DOORS servers as a Nexus server supports self-referencing, self-describing, and bootstrapping processes among the system components.

Scribe registrars provide read-write access to the NPDS cyberinfrastructure, enabling web users or automated agents to make additions, deletions, or revisions to the NPDS records at Nexus diristries, PORTAL registries, and DOORS directories. Read-write APIs for Scribe registrars are not part of the

Table II
FUNCTIONS OF PORTAL AND DOORS SERVERS FOR RESOURCE AGENTS AND USERS

	PORTAL	DOORS
System	Enforce generic root and specific master schemas	Access PORTAL generic root and specific master schemas
	Recommend list of related master servers	Redistribute list of related master PORTAL servers
	Recommend list of related primary DOORS servers	Redistribute list of related primary servers
Agent	Create and maintain agent account at master server	Create and maintain agent account at primary server
	Create and maintain resource records at master server	Create and maintain resource records at primary server
	Register label and tags for each resource record	Publish location and description for each resource record
	Publish cross-references for each resource record	Publish provenance and distribution for each resource record
User	Map label to primary and secondary DOORS servers	Map label to location
	Map label or tags to cross-references	Map tag to location
	Map cross-reference to label and tags	Search semantic statements in descriptions
	Search non-semantic strings in labels or tags	Search non-semantic strings in labels or tags
	Obtain owner information and other metadata	Obtain record identification and authentication

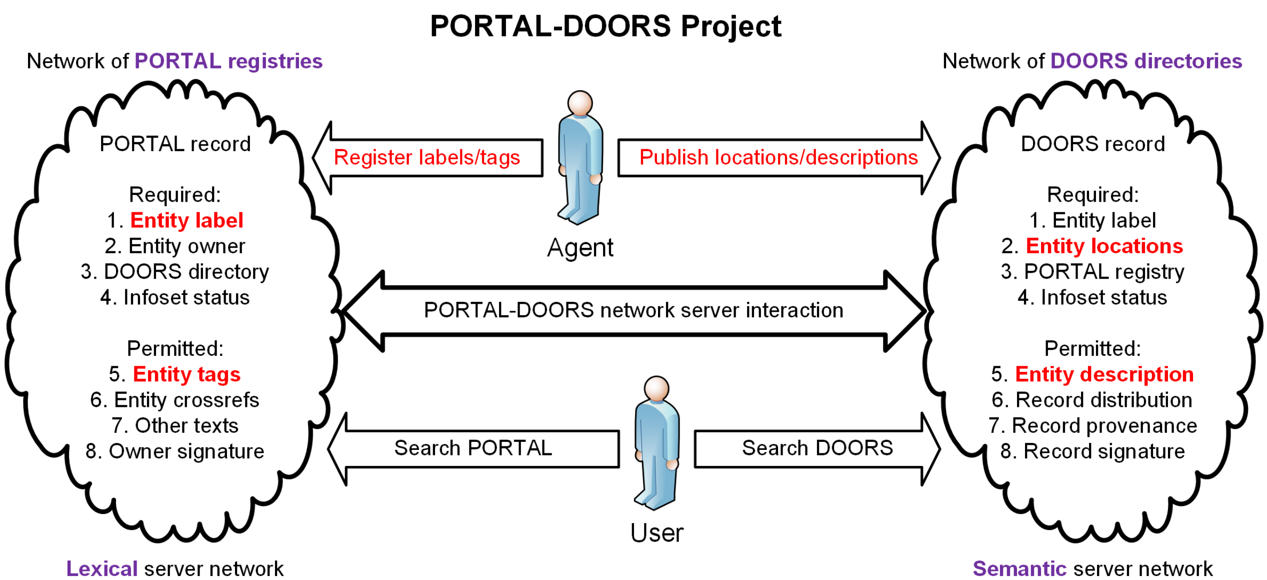

Figure 1. PORTAL-DOORS Project: Resources are registered within and published to the NPDS cyberinfrastructure by agents for retrieval by users. The system has both lexical and semantic networks: PORTAL registries manage lexical information via character string processing, and DOORS directories manage semantic graphs via the XML/RDF/OWL/SPARQL technology stack.

required specification for NPDS, thereby permitting flexibility and compatibility with a diversity of authentication methods and implementations for different independent communities maintaining a wide variety of Nexus diristries, PORTAL registries, and DOORS directories. Web applications at sites such as the PDP Scribe Registrar (www.PORTALDOORS.net) and BHA Scribe Registrar (www.BrainHealthAlliance.net) provide a user-friendly interface for some example registrars.

V. HDMM Architectural Style

In a manner analogous to IRIS-DNS [6], the NPDS cyberinfrastructure has adopted the Hierarchically Distributed Mobile Metadata architectural style [5] in which a distributed network of metadata management servers interoperate via both hierarchical authorities and shared peer-to-peer forwarding, caching, and redistribution. This architectural style and design philosophy was adopted with the goal of sharing and redistributing data and metadata as efficiently as possible.

Distributed Control: "Pervasively distributed and shared infrastructure, content, and control of content" [7, pg. 163, Sec. 4, itm. 1]. Distributed and shared control of content contained in the NPDS cyberinfrastructure provides a redundant system that avoids single points of failure and prevents monopolistic control of information by any single for-profit corporation or censoring organization.

Hierarchical Authorities: "A hierarchy of both authoritative and non-authoritative servers" [7, pg. 163, Sec. 4, itm. 2]. Through the distribution of both authoritative and non-authoritative servers, the system retains the ability of independent governance and administrative control over data redistribution while still remaining a distributed and redundant network [8].

Mobile Metadata: "A focus on moving the mobile metadata for who what where as fast as possible" [7, pg. 164, Sec. 4, itm. 3]. The distribution of *who what where* metadata within the system should be searchable, available and redistributable as efficiently as possible. In this hierarchy, local and caching non-authoritative servers acting as peers can redistribute data whereas authoritative servers function as points of control through which authenticated data can be published.

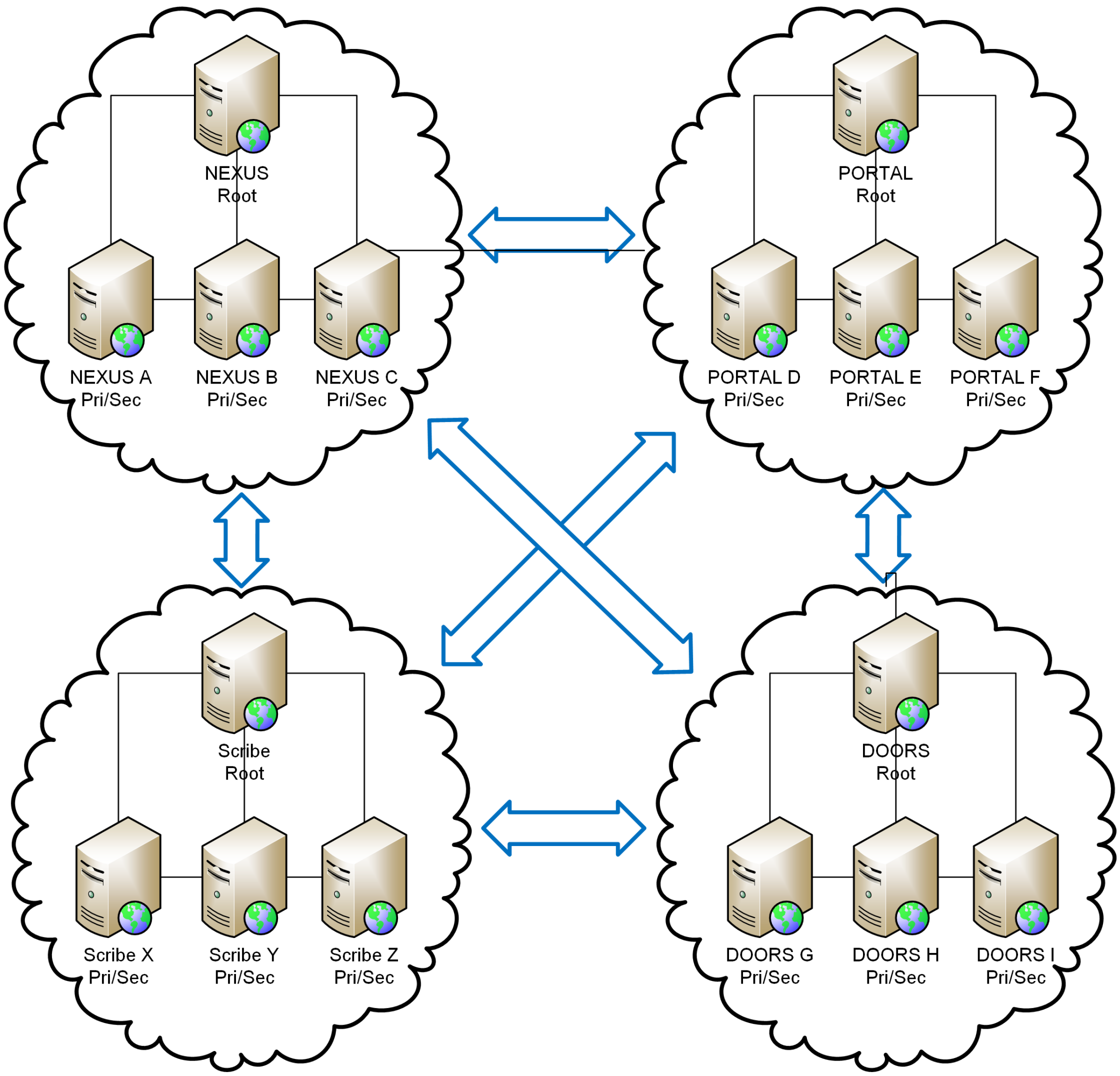

Figure 2. NPDS Server Network: With connections between hybrid Nexus diristries, lexical PORTAL registries, semantic DOORS directories, and Scribe registrars, the NPDS server network supports publishing and distribution of data, metadata, information and knowledge from and/or about resources.

Separation of Concerns: "A separation of concerns with registries for identifying resources and directories for locating resources" [7, pg. 164, Sec. 4, itm. 4]. Lexical registries for identifying resources and semantic directories for locating those resources maintain separate functionalities from to promote modularity of requirements, code and operations. This separation of concerns fosters flexibility for lexical-only, semantic-only, and hybrid lexical-semantic applications.

Identifier Selection: "A relative freedom of choice in the selection of identifiers" [7, pg. 164, Sec. 4, itm. 5]. NPDS permits globally unique identifiers to be simply URIs without any requirement for a hierarchical structuring such as that which is present in URLs. Because NPDS also permits unrestricted choice for identifiers as long as globally unique, monopolistic control of these identifiers can be prevented.

VI. Social Engineering with FAIR Metrics

In addition to the software architecture and experimental science perspectives, PDP has also adopted a social engineering perspective for the DREAM principles by including principles related to the FAIR metrics. "We define and formulate these metrics to quantify FAIR citing behavior for the purpose of promoting established traditional standards that repudiate plagiarism when publishing scholarly literature" [12, pg. 1, Sec. Introduction, par. 1]. The FAIR metrics have been created as a response to the current practice of measuring the scientific merit of a research publication based on the number of citations it receives [20]. The FAIR metrics have been designed to encourage those who properly cite previously published work fairly, while discouraging those who have failed to cite and discuss the relevant and related literature. Moreover, the FAIR metrics have been developed to target plagiarism of ideas [12], rather than simply plagiarism of words [21]. Thus, the FAIR metrics family consists of four main measures indicative of different aspects of an author's citation practices: F_1, F_2, F_3, and F_4. Alternative algorithms are currently under development for NLP-based extraction and comparison of RDF triples in computational experiments to validate these FAIR metrics [12].

Table III
HIERARCHICALLY DISTRIBUTED MOBILE METADATA (HDMM) IN IRIS-DNS AND NPDS

	IRIS-DNS System	NPDS System
Dynamic metaphor	A distributed communications network brain of nodal neurons continuously updating, exchanging, and integrating messages about ‘who what where’	
Static metaphor	A simple phonebook	A sophisticated library card catalogue
Registering system	IRIS registries	PORTAL registries, Nexus diristries
– Entity registered	domain	resource
– Identified by	unique name	unique label with optional tags
Publishing system	DNS directories	DOORS directories, Nexus diristries
– Attributes published	address and aliases	locations and descriptions
– Specified by	IP numbers	URIs, URLs, RDF triples referencing OWL ontologies
Entity identification	Hierarchical URL	Non-hierarchical URI
Record distribution	Hierarchical request forwarding and response caching	Hierarchical request forwarding and response caching
Forwards requests	Yes	Yes
Caches responses	Yes	Yes
Serves lexical web	Yes, mapping character name to numeric address	Yes, mapping character label to URL for IRIS-DNS
Serves semantic web	No, because IRIS-DNS does not use RDF triples	Yes, mapping character label to semantic description
Crosslinks entities	No	Yes, mappings from descriptions to other resources
Crosslinks systems	No	Yes, mappings from crossreferences to other systems

VII. PDP-DREAM ONTOLOGY

To codify the principles outlined and reviewed above, an ontology named PDP-DREAM has been created for the PORTAL-DOORS Project and DREAM principles in order to consolidate the entire collection of principles (those for software architecture, experimental science, and social engineering) into a formal specification. This PDP-DREAM ontology has been developed in OWL 2.0 [22]. The current version of this ontology has four main sections corresponding to the DREAM principles, the HDMM architectural style, the NPDS cyberinfrastructure, and the FAIR metrics.

DREAM principles: As the core foundation of the NPDS cyberinfrastructure, PDP has developed the DREAM principles with the acronym DREAM for the main phrase *Discoverable Data with Reproducible Results for Equivalent Entities with Accessible Attributes and Manageable Metadata*. As an acronym, DREAM also represents various other alternative phrases including those summarized in Table I.

- D for Discoverable Data refers to data and/or metadata which is democratized, decentralized, distributed and discoverable, meaning that it can be searched and found easily by users.
- R for Reproducible Results refers to reproducibility in experimental science, to reproducibility in transmission and storage of information, data and metadata in engineering technology, and to the reusability of resources and records from repositories.
- E for Equivalent Entities refers to the critical question of asking whether two entities are equivalent, ie, of identifying and characterizing the two entities as either the same as or different from each other, whether in experimental science with observed facts and artifacts, or in scholarly research literature with concept similarity detection of ideas and statements, while allowing for the distinction between an original entity in contrast to enhanced or extended versions of the entity.
- A for Accessible Attributes refers to assuring that all aspects of the data and/or metadata are easily available, accessible and accurate.
- M for Manageable Metadata refers to the multi-level metadata with *metadata about metadata* [7] and data that uniquely characterizes NPDS as a data management system for metadata and data.

HDMM architectural style: The HDMM section of the ontology documents the HDMM architectural style and delineates the design principles which characterize both IRIS-DNS and NPDS [5], [7], [8] and govern the distributed network principles that are common to both of these systems.

NPDS cyberinfrastructure: The NPDS section of the ontology focuses on the design principles specific to the NPDS cyberinfrastructure including the PORTAL registries, DOORS directories, Nexus diristries, Scribe registrars, the computational components, the functional services, XML and JSON messaging schemas, and NPDS web service APIs.

FAIR metrics: The FAIR section of the ontology specifies the definitions and formulas for the FAIR metrics as well as the associated FAIR principles for the promotion of fair citation practices and the prevention of all kinds of plagiarism including the plagiarism of words, pictures and ideas. The description of these FAIR citation principles also includes details necessary for peer and editorial review in scholarly research publishing [13].

VIII. CONCLUSION

The PORTAL-DOORS Project (PDP) has been pursued to develop the Nexus-PORTAL-DOORS-Scribe (NPDS) cyberinfrastructure as a distributed network system of data repositories to support identifying, registering, storing, publishing, describing, locating, linking, sharing, distribution and redistribution of data, metadata, information, and knowledge on the web. Based on the HDMM architectural style in a manner analogous to IRIS-DNS, NPDS focuses on delivering *who what where* information as efficiently as possible. NPDS consists of lexical PORTAL registries for registering labels and tags, semantic DOORS directories for publishing locations and descriptions, Nexus diristries for integrated combinations of PORTAL registries and DOORS directories, and Scribe registrars for read-write access to the Nexus, PORTAL, and DOORS repositories. As novel contribution in the current work reported here, we have combined our original principles from PDP, HDMM, and NPDS together with additional principles for scientific reproducibility and social engineering related to the FAIR metrics for promoting fair citation and preventing plagiarism in scholarly research publishing. We call this new consolidated collection of principles the DREAM principles with acronym DREAM for the phrase *Discoverable Data with Reproducible Results for Equivalent Entities with Accessible Attributes and Manageable Metadata*. To codify these DREAM principles as a concrete artifact for the semantic web, and thus to operationalize their use, we developed an OWL 2.0 ontology that we named the PDP-DREAM ontology.

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