

OIL: A Standard Proposal for the Semantic Web

Dieter Fensel¹, Frank van Harmelen¹, and Ian Horrocks²

¹ Vrije Universiteit Amsterdam

² University of Manchester (sub-contractor of the Vrije Universiteit Amsterdam)

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Vrije Universiteit Amsterdam (VU)

Faculty of Sciences, Division of Mathematics and
Computer Science
De Boelelaan 1081a
1081 HV Amsterdam, the Netherlands
Fax and Answering machine: +31-(0)20-872 27 22
Mobil phone: +31-(0)6-51850619
Contactperson: Dieter Fensel
E-mail: dieter@cs.vu.nl

University of Karlsruhe

Institute AIFB
Kaiserstr. 12
D-76128 Karlsruhe, Germany
Tel: +49-721-608392
Fax: +49-721-693717
Contactperson: R. Studer
E-mail: studer@aifb.uni-karlsruhe.de

**Schweizerische Lebensversicherungs- und
Rentenanstalt / Swiss Life**

Swiss Life Information Systems Research Group
General Guisan-Quai 40
8022 Zürich, Switzerland
Tel: (41 1) 284 4061, Fax: (41 1)284 6913
Contactperson: Ulrich Reimer
E-mail: Ulrich.Reimer@swisslife.ch

British Telecommunications plc

BT Adastral Park
Martlesham Heath
IP5 3RE Ipswich, UK
Tel: (44 1473)605536, Fax: (44 1473)642459
Contactperson: John Davies
E-mail: John.nj.Davies@bt.com

CognIT a.s

Busterudgt 1.
N-1754 Halden, Norway
Tel: +47 69 1770 44, Fax: +47 669 006 12
Contactperson: Bernt. A.Bremdal
E-mail: bernt@cognit.no

EnerSearch AB

SE 205 09 Malmö, Sweden
Tel: +46 40 25 58 25; Fax: +46 40 611 51 84
Contactperson: Hans Ottosson
E-mail: hans.ottosson@enersearch.se

Administrator Nederland BV

Julianaplein 14B
3817CS Amersfoort, NL
Tel: (31-33)4659987, Fax: (31-33)4659987
Contactperson: Jos van der Meer
E-mail: Jos.van.der.Meer@administrator.nl

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1. OIL: A Proposal for the Semantic Web

1.1 The language

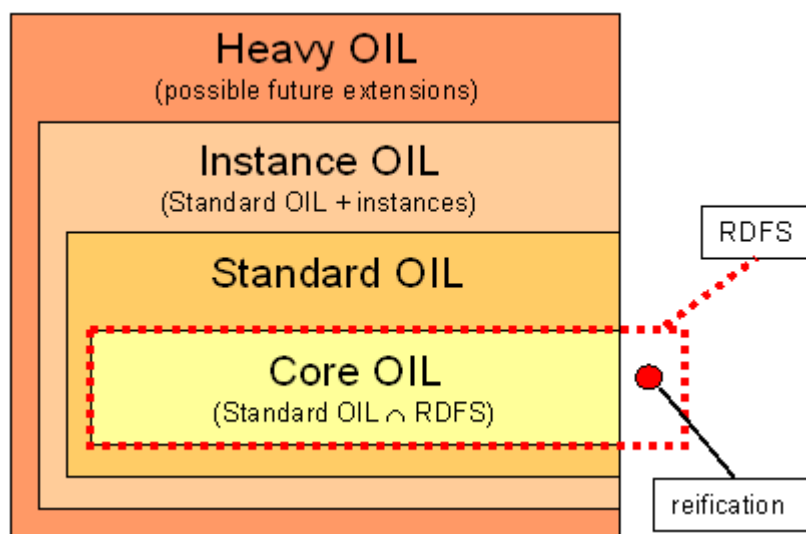
The current Web is aimed at human readers. The inability to process the contents of information by machines seriously hampers the functionality of the current Web. The vision of the Semantic Web aims at creating a Web where information can be "understood" by machines as well as by humans. **OIL** (<http://www.ontoknowledge.org/oil>) is designed to be exactly such a representation of machine-accessible semantics of information on the Web. OIL is the acronym of "Ontology Inference Layer", or "Ontology Interchange Language".

Design idea of OIL

OIL synthesises work from three different communities to achieve the ambitious aim of providing a general purpose markup-language for the Semantic Web:

- **Frame-based systems:** OIL incorporates the essential modelling primitives of frame-based systems, being based on the notion of a concept and the definition of its superclasses and slots. OIL also treats slots as first class objects that can have their own properties (e.g., domain and range) and can be arranged in a hierarchy.
- **Description logics:** OIL inherits from DLs both their formal semantics and efficient reasoning support.
- **Web standards: XML and RDF.** First, OIL has a well-defined syntax in XML based on a DTD and a XML schema definition. Second, OIL is defined as an extension of the Resource Description Framework RDF and its schema definition language RDF Schema. OIL extends this approach to a full-blown modelling language.

OIL presents a layered approach to a standard ontology language. Each additional layer adds functionality and complexity to the previous layer. This is done such that agents (humans or machines) who can only process a lower layer can still partially understand ontologies that are expressed in any of the higher layers. The picture below sketches the relation between the OIL dialects and RDFS.



- Core OIL coincides largely with RDF Schema (with the exception of the reification features of RDF Schema). This means that even simple RDF Schema agents are able to process the OIL ontologies, and pick up as much of their meaning as possible with their limited capabilities.
- Standard OIL is a language intended to capture the necessary mainstream modelling primitives that both provide adequate expressive power and are well understood thereby allowing the semantics to be precisely specified and complete inference to be viable.
- Instance OIL includes a thorough individual integration. While the previous layer - Standard OIL - included modelling constructs that allow individual fillers to be specified in term definitions, Instance OIL includes a full-fledged database capability.
- Heavy OIL may include additional representational (and reasoning) capabilities.

Application enabled by OIL

Machine-processable representations of ontologies will be crucial to many applications of the semantic Web. We briefly mention only a few:

- *Search engines*: The problems caused by simple keyword-matching can be alleviated if search engines search on the semantic concepts that underlie the information in web-pages.
- *E-commerce*: Comparison-shopping can be achieved when web-shops offer their catalogues in machine-processable formats, with links to explicit and shared ontologies that are used to construct mappings between these catalogues.
- *Knowledge management*: Explicit ontologies are the most promising technical vehicle for transforming document repositories into proper knowledge repositories embedded in an increasing number of companies' Intranet.

1.2 Tool support

OntoEdit (Ontology Engineering Environment, <http://ontoserver.aifb.uni-karlsruhe.de/ontoedit>) developed at the Knowledge Management Group of the AIFB Institute at the University of Karlsruhe, is a general ontology editor customized for OIL. It is developed as part of the On-to-knowledge project.

OILedit, a freely available and customized editor for OIL, developed by the University of Manchester. Its development was sponsored by a German internet start-up company Interprice (<http://www.interprice.com>) and the Vrije Universiteit Amsterdam.

Protégé (an ontology editor, <http://www.smi.stanford.edu/projects/protege/>) built by the University of Stanford is currently extended for OIL, again based on funding provided by Interprice.

Inference engines can be used to reason about ontologies, helping both to build them and to use them for advanced information access and navigation. OIL uses the *FaCT system* (Fast Classification of Terminologies, <http://www.cs.man.ac.uk/fact>) to provide reasoning support for ontology design, integration and verification.

1.3 Organisational structure

We set up a large international consortium to facilitate the dissemination of the project results of On-to-knowledge. The OIL Steering Committee consists of the following members:

- Stefan Decker, Stanford University
- Dieter Fensel, Vrije Universiteit Amsterdam Nederland
- Frank van Harmelen, Vrije Universiteit Amsterdam Nederland
- Ian Horrocks, Department of Computer Science University of Manchester
- Deborah McGuinness, Stanford University
- Peter F. Patel-Schneider, Bell Labs Research
- Steffen Staab, Institute AIFB, University of Karlsruhe
- Lynn Stein, Massachusetts Institute of Technology

The Advisory Board has the following members:

- Stuart Aitken, John Kingston and Austin Tate, Artificial Intelligence Applications Institute (AIAI)
- Jeen Broekstra, Christiaan Fluit, Jos van der Meer, Administrator Nederland
- John Davies, John Hughes, Uwe Krohn, BT Labs.
- Bernt A. Bremdal and Robert Engels, CognIT
- Rüdiger Klein, DaimlerChrysler
- Fredrik Ygge, EnerSearch
- Heinz Jürgen Müller, E24 T-Nova Deutsche Telekom Innovationsgesellschaft mbH
- Alain Léger, FT R&D : The R&D Centre of France Télécom
- Masahiro Hori, IBM (Japan)
- Mike Brown and Vincent Power, Interprice technologies
- Richard Benjamins, iSOCO, Intelligent Software Components, S. A.
- Jürgen Angele, Ontoprise
- Enrico Motta, Knowledge Media Institute, Open University UK .
- Robin McEntire, SmithKline Beecham
- Peter Karp, SRI International's Artificial Intelligence Center (AIC)
- Monika Crubezy, William Grosso, and Mark Musen, Knowledge Modeling Group at Stanford Medical Informatics, Stanford University
- Ulrich Reimer and Martin Staudt, Swiss Life
- Pim Borst, Unilever
- Guus Schreiber and Bob Wielinga, SWI, University of Amsterdam
- Heiner Stuckenschmidt, University of Bremen, Germany
- Michael Erdmann, Alexander Maedche, Rudi Studer, York Sure, Institute AIFB, University of Karlsruhe
- Carole Goble and Sean Bechhofer, Department of Computer Science, University of Manchester
- Hans Akkermans, Ying Ding, Michel Klein, Borys Omelayenko, Vrije Universiteit Amsterdam, Nederland

OIL is the product of a cooperation between various research groups in Academia and

industry, many of which are not even part of the On-to-knowledge consortium.

1.4 Resources and white papers

- The general web page is at: <http://www.ontoknowledge.org/oil>
- An incomplete list of papers is provided below:
 - S. Decker, F. van Harmelen, J. Broekstra, M. Erdmann, D. Fensel, I. Horrocks, M. Klein, and S. Melnik: The Semantic Web - on the respective Roles of XML and RDF. To appear in *IEEE Internet Computing*.
 - D. Fensel et al.: OIL in a nutshell In: Knowledge Acquisition, Modeling, and Management, Proceedings of the European Knowledge Acquisition Conference (EKAW-2000), R. Dieng et al. (eds.), Lecture Notes in Artificial Intelligence, LNAI, Springer-Verlag, October 2000.
 - D. Fensel, F. van Harmelen, H. Akkermans, M. Klein, J. Broekstra, C. Fluyt, J. van der Meer, H.-P. Schnurr, R. Studer, J. Davies, J. Hughes, U. Krohn, R. Engels, B. Bremdahl, F. Ygge, U. Reimer, and I. Horrocks: OnToKnowledge: Ontology-based Tools for Knowledge Management. In *Proceedings of the eBusiness and eWork 2000 (EMMSEC 2000) Conference*, Madrid, Spain, October 2000.
 - D. Fensel: Relating Ontology Languages and Web Standards. In J. Ebert et al. (eds.), *Modelle und Modellierungssprachen in Informatik und Wirtschaftsinformatik, Modellierung 2000*, St. Goar, April 5-7, 2000, Fölbach Verlag, Koblenz, 2000.
 - J. Broekstra, M. Klein, D. Fensel, S. Decker, and I. Horrocks: Adding formal semantics to the Web: building on top of RDF Schema. In *Proceedings of the Workshop Semantic Web: Models, Architectures and Management*, Lisbon, September 21, 2000, following the Fourth European Conference on Research and Advanced Technology for Digital Libraries (ECDL'2000).
 - S. Decker, D. Fensel, F. van Harmelen, I. Horrocks, S. Melnik, M. Klein, and J. Broekstra: Knowledge Representation on the Web. In *Proceedings of the 2000 International Workshop on Description Logics (DL2000)*, Aachen, Germany, August 2000.
 - M. Klein, D. Fensel, F. van Harmelen, and I. Horrocks: The relation between ontologies and schema-languages: Translating OIL-specifications in XML-Schema. In *Proceedings of the Workshop on Applications of Ontologies and Problem-solving Methods, 14th European Conference on Artificial Intelligence ECAI'00*, Berlin, Germany August 20-25, 2000.
 - D. Fensel, M. Crubezy, F. van Harmelen, and I. Horrocks: OIL & UPML: A Unifying Framework for the Knowledge Web. In *Proceedings of the Workshop on Applications of Ontologies and Problem-solving Methods, 14th European Conference on Artificial Intelligence ECAI'00*, Berlin, Germany August 20-25, 2000.
 - H. Stuckenschmidt: Using OIL for Intelligent Information Integration In: Proceedings of the Workshop on Applications of Ontologies and Problem-Solving Methods at ECAI 2000, 2000.
 - H. Stuckenschmidt and H. Wache: Context Modeling and Transformation for Semantic Interoperability In: Knowledge Representation meets Databases -

Proceedings of the Workshop at ECAI 2000, 2000.

2. Industrial and Academic User Community of OIL

We actively collaborate with the following entities on current or near-future OIL deployment:

- Amsterdam Medical Centre
- Boeing
- Daimler-Chrysler
- Interprice
- Ontoprise
- Content Europe

Besides of course the On-To-Knowledge industrial partners are:

- CognIT
- Administrator
- BT
- Swiss Life
- Enersearch

Some of the collaborating academic partners outside the consortium are:

- University of Bremen, Germany
- University of Amsterdam, NL
- Open University, Milton Keynes, UK
- University of Stanford, Database group, Knowledge Systems Lab, and the Medical Informatics Department

Collaborating projects are

- IST Project in the Information Society Technologies (IST) Programme for Research, Technology Development & Demonstration under the 5th Framework Programme: IBROW: An Intelligent Brokering Service for Knowledge-Component Reuse on the World Wide Web. Project partners are the University of Amsterdam (co-ordinator); the Open University, Milton Keynes, England; the Spanish Council of Scientific Research (IIIA) in Barcelona; the Institute AIFB, University of Karlsruhe; and the Vrije Universiteit Amsterdam (1998-2002). <http://www.swi.psy.uva.nl/projects/ibrow/home.html>. IST-1999-19005, open domain.
- IST Project in the Information Society Technologies (IST) Programme for Research, Technology Development & Demonstration under the 5th Framework Programme: MKBEEM: Multilingual Knowledge Based European Electronic Marketplace. Project partners are France Télécom-CNET, France; Centre National de la Recherche Scientifique (CNRS), délégation Languedoc Roussillon, France; Ellos Oy, Finland; Fiduciaire juridique et fiscal de France (FIDAL), France; National Technical University of Athens (NTUA), Greece; Sema Group sae, Spain; Société Nationale des

Chemins de Fer Français (SNCF), France; Technical Research Center of Finland (VTT), Finland; Tradezone International Ltd, United Kingdom; Universidad Politécnica de Madrid (UPM), Spain (2000-2002). <http://www.linglink.lu/hlt/p&p99/> (then select MKBEEM). IST-1999-10589, key action II.

- IST Project in the Information Society Technologies (IST) Programme for Research, Technology Development & Demonstration under the 5th Framework Programme: CoMMA (Corporate Memory Management through Agents). Project partners are: ATOS Integration, France (Coordinator); CSELT, Italia; INRIA, France; LIRMM, Université de Montpellier II, France; Parma University, Italia; T-NOVA, Germany (2000-2002). <http://www.ii.atos-group.com/sophia/comma/HomePage.htm>. IST-1999-12217, KEY ACTION: II.1.2.
- The UK Interdisciplinary Research Collaboration in Advanced Knowledge Technologies (AKT) (<http://www.aktors.org>), a six year (2000-2006) programme which has overlapping objectives.

3. DAML and W3C

DAML is a major, well-funded initiative by Darpa aimed at bringing together the many ongoing semantic web efforts, and focused on bringing ontologies to the web. The DAML language (<http://www.daml.org/>) inherits many aspects from OIL, and the capabilities of the two languages are relatively similar. However, there are also some important differences. OIL achieves a greater backward compatibility with RDF Schema than DAML and OIL has been designed to enable reasoning services that are sound and complete as well as efficient. Some constructions in DAML make similar reasoning services for DAML impossible.

Together with the members of the DAML initiative we recently set up a *Joint EU/US ad hoc Agent Markup Language Committee*.¹ The committee as currently constituted is:

Chair: Mike Dean

Editors: Dan Connolly, Lynn Andrea Stein, Deb McGuinness

Members: Dan Brickley, Stefan Decker, Pat Hayes, Jeff Heflin, Ian Horrocks, Ora Lassila, Frank Van Harmelen

EU Advisor: Dieter Fensel

US Advisor: Tim Berners-Lee

Government Advisors: Jim Hendler, Hans-Georg Stork

We already proposed a unifying language proposal called **DAML-OIL**.²

Recently, there also has been an *Activity Proposal: Semantic Web*³ of the World Wide Web Consortium (W3C) asking for the following activities:

- Continue the work of the RDF Interest Group

¹ <http://lists.w3.org/Archives/Public/www-rdf-logic/2000Nov/0093.html>

² <http://www.cs.man.ac.uk/~horrocks/DAML-OIL/>

³ <http://www.w3.org/2000/11/SemanticWebProposal>

- Charter a Working Group to consider revisions to the RDF Model and Syntax Recommendation
- Complete work on the RDF Schema specification
- Coordinate with selected non-W3C initiatives and individual activities working on Semantic Web technologies. This coordination includes, but is not limited to, DCMI, DAML, OIL, and SHOE,
- Charter additional working or interest groups identified as necessary in supporting the above objectives
- Create an advanced development project to design and develop supporting XML and RDF technologies

The Vrije Universiteit is member of the Advisory board of the W3C and will support this activity proposal.

4. FIPA

We started activities for submitting OIL as a standard proposal to FIPA⁴, a standardization body related to Agent-based software. FIPA is an organisation aimed at producing standards for the interoperation of heterogeneous software agents. We plan to propose OIL as a *FIPA Content Language (CL)*⁵ defining the content of messages between agents. We already had initial communication with Mark Greaves (Boeing), who is the chair of the FIPA Agent Communication technical committee (TC C) addressing FIPA's basic responsibilities in the area of specifying and maintaining an agent communication language, along with libraries of predefined communicative act types, interaction protocols and content languages.

5. Ontoweb: A Network of Excellence Proposal

OntoWeb: Ontology-based information exchange for knowledge management and electronic commerce is a proposal for a thematic network currently under submission. Coordinator is the Vrije Universiteit Amsterdam.

The goal of the OntoWeb Network is to bring together researchers and industrials coming from the research and applications areas above, promoting interdisciplinary work and strengthening the European influence on Semantic Web standardisation efforts such as those based on RDF and XML. Europe's cultural diversity and multi linguality, together with the strong scientific competences existing in the ontology field, may give Europe a unique opportunity to fully exploit ontology-based technology and to play a leading role in these emerging area.

The main long term goals of the network are:

⁴ <http://www.fipa.org/>

⁵ <http://www.fipa.org/repository/cls.html>

- To stimulate and support the transfer of research on the Semantic Web from academia to industry;
- To stimulate the translation from industrial needs to technical and scientific problems;
- To represent and co-ordinate ontology-related research being carried out in different research areas, such as: Web Markup Languages, Knowledge Acquisition, Knowledge Engineering, Knowledge Representation, Information systems and database integration, Information Retrieval, Language Engineering, Digital Libraries, Software Agents, and Machine Learning;
- To disseminate information, research and application results about ontologies and related fields;
- To represent the European ontology community world wide and co-operating with related initiatives like DAML in the US;
- To enhance the training in ontology-related technologies at the European level;
- To distribute results and stimulate applications in all areas, with special emphasis on Web-based applications, electronic commerce, and information integration;
- To cooperate with content standardisation committees to promote the development of ontology-based standards and the harmonization/interoperability across different
- standards (with special emphasis on standards being developed for electronic commerce in the B2B area);
- To cooperate with language standardisation committees as the W3C to promote the development of standard languages for meta data (future versions of RDF and RDFS);

Specific Goals of the Network are:

- Maintaining and extending an information service for scientists, practitioners and students. Electronically, information will be made available about scientific events and developments, courses, companies, and research institutions, material for research such as software and benchmarking problems.
- Producing an overview of current research and development activities and an outline of main technical and scientific issues to be addressed in the near future in the form of a technical roadmap.
- Demonstrating to industry how ontologies can be applied to particular problems in Knowledge Management, Electronic Commerce, and Enterprise Integration, and identifying problems in industry that can be addressed in scientific research.
- Improving the co-operation with related scientific fields such as Web standards, Knowledge Engineering, Knowledge Representation, Information systems and database integration, Information Retrieval, Language Engineering, Digital Libraries, Software Agents, and Machine Learning.

We will use Ontoweb as a major channel for further disseminating OIL and for coordinate our cooperation with Non-EU partners. Currently we have the following members:

Academic partners, providing substantial research contribution to the knowledge web.

- P1. VU, Vrije Universiteit Amsterdam, Netherlands
- P2. UPM, Universidad Politecnica de Madrid, Spain
- P3. UPS, L.R.I, University of Paris-Sud, France
- P4. AIFB, University of Karlsruhe, Germany
- P5. VUM, University of Manchester, UK

- P6. OU, Open University, UK
 P7. VUB, Vrije Universiteit Brussel, Belgium
 P8. LADSEB-CNR, Institute of Systems Science and Biomedical Engineering, Consiglio Nazionale delle Ricerche, Italy
 P9. INRIA, France
 P10. SWI/UvA - University of Amsterdam, Netherlands
 P12. DSI -Università di Modena e Reggio Emilia, Italy
 P13. CNR - ITBM, Italy
 P15. AIAI, University of Edinburgh, UK
 P16. QMW: Queen Mary and Westfield College
 P19. UIA, Universiteit Antwerpen (UIA), Belgium
 P20. Hannover, Universitat Hannover, Germany
 P21. RWTH – University of Technology (RWTH) Aachen, Germany
 P24. DFKI, Deutsches Forschungszentrum fuer Kuenstliche Intelligenz GmbH, Language Technology Lab, Germany
 P25. LIMOS, Blaise Pascal University, Clermont-Ferrand, France
 P32. University of Aberdeen, Department of Computing Science, UK
 P33. GU, University of Glasgow, UK
 P39. UCV, The Computer Science and Engineering Department, University of Craiova, Romania
 P43. AI Group – Department of Mathematics and Computer Science – University of Bremen, Germany
 P44. FORTH - Institute of Computer Science, Greece.
 P46. CWI, Institute of the Stichting Mathematisch Centrum, the Netherlands
 P47. ZSU - Zaporozhye State University, Ukraine
 P48. ECS The University of Southampton, UK
 P49. LML – Linguistic Modelling Laboratory, Bulgarian Academy of Sciences, Bulgaria
 P50. Kharkov State Technical University of Radioelectronics, Ukraine
 P54. IASI (Institute of systems analysis and informatics), Italy
 P55. Swiss Federal Institute of Technology, Lausanne - Database Laboratory (LBD), Swiss

Industrial partners from Europe, providing either leading technology or providing best-practice cases and interesting applications

- P11. FT R&D : The R&D Centre of France Télécom, France
 P14. Sail Labs, Sail Labs BVBA, Antwerp, Belgium
 P17. E24 – T-Nova Deutsche Telekom Innovationsgesellschaft mbH
 P18. iSOCO, Intelligent Software Components, S. A., Spain
 P23. Swiss Life, Switzerland
 P27. CognIT, Norway
 P29. Biovista, Greece
 P34. HLS, High Level Systems Ltd, UK
 P35. CRE, Canon Research Centre Europe Ltd, UK
 P36. Ontoprise GmbH, Germany
 P37. PricewaterhouseCoopers, Luxembourg
 P38. Stichting ELSNET, the Netherlands
 P40. Interprice, Germany
 P41. Institut der deutschen Wirtschaft Köln Consult GmbH (IW Consult), Germany

- P42. Koninklijke Cooperatie Cosun U.A. (Cosun), the Netherlands
- P51. British Telecom (BT), UK
- P52. DaimlerChrysler AG, Germany
- P53. SAI – Sirma AI, Ltd, Bulgaria

Non-European partners. The WWW and the Knowledge Web have an international character. Therefore, non-European partners fitting either the Academic or the Industrial profiles above are welcome.

- P22. Stanford-SMI, Stanford Medical Informatics, USA
- P26. UMCP, University of Maryland, College Park, USA
- P28. ISI, University of Southern California, USA
- P30. IBM Japan, Japan
- P31. Stanford University, InfoLab
- P45. Bell Labs Research, USA

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⁶ He gave the thing the name.