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FEATURE ARTICLE

THE SEMANTIC WEB: AN INTERVIEW WITH TIM BERNERS-LEE

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Introduction: If you are a reader of this journal, it is likely that you are aware that one of the main goals of the W3C is nearing fruition: the deployment of the core set of standards needed to enable the next level of the Web itself. These standards are the extension of the original vision of the inventor of the Web, Tim Berners-Lee.

After years of development, these specifications will enable users to search not only for documents that contain data, but also for the desired data itself, through “semantic” identification and location techniques. The result of implementing these standards will be the creation of a next-generation “Semantic Web.” This new Web will be capable of supporting software agents that are able not only to locate data, but also to “understand” it in ways that will allow computers to perform meaningful tasks with data automatically and on the fly that today must be done manually and episodically by computer users. Or, as summarized in a *Scientific American* article written by Berners-Lee, Jim Hendler and Ora Lassila in 2001, “The Semantic Web is an extension of the current Web in which information is given well-defined meaning, better enabling computers and people to work in cooperation.”

All of which would lead one to assume that the deployment of these standards will be immediate and enthusiastic. Unfortunately, when one seeks to describe the Semantic Web in greater detail, it tends to become more nebulous rather than clearer to the uninitiated. Were the standards created to allow better search engines to be built? No, but search engine technology will benefit from incorporating Semantic Web standards. Is it a new type of Web? No, but it will allow more to be done with the Web we have. Will it enable new “Killer Apps?” No – it is intended to be a Killer App.¹

The result is that Tim Berners-Lee, who conceived the Semantic Web and has championed the development of the standards and supporting materials (primers, test cases, references and overviews) that will make it possible, has found it necessary to proselytize on behalf of the Semantic Web, just as he did ten years ago when descriptions of the now-familiar Web were met with blank stares.

In support of those efforts, we are honored to present a detailed interview with Berners-Lee that focuses exclusively on the Semantic Web, and why he believes its realization is so important.

Questions and Answers: Our interview was intended to help those that do not yet have the Semantic Web in focus gain an understanding of what the Semantic Web will (and will not) be, what we can look forward to using it for, and how it is likely to become real. Our questions were divided into the following six categories:

- **Vision:** Why build a Semantic Web now, rather than add other capabilities at this point in time, and what new capabilities will the Semantic Web have?
- **Status:** Who is already committed to create the Semantic Web, and how do we get the rest on board?

¹ This article does not focus on the technical details of the Semantic Web. To learn more about how the Semantic Web will work, see the links at the end of this interview.

- **Critics:** What has worked well and what has not proceeded so smoothly in developing Semantic Web standards, and what are the things that critics don't "get" about the Semantic Web?
- **Business Reality:** What are the biggest challenges to bringing the Semantic Web into being?
- **Infrastructure:** Will other standards be needed in the future to take full advantage of the Semantic Web, and who will develop them?
- **Users:** What will it be like to use the Semantic Web?

Tim Berners-Lee's answers to our questions are provided in their entirety, without editing for considerations of space or otherwise. (For further context, see this issue's Editorial and Trends article.)

CSB: *Before we get into specifics, what is it like bringing your vision to the world for the second time of what the Web can be, now that the design for "version 2.0" has been completed?*

TBL: Let me start by saying our work in promoting rather than developing the Semantic Web technologies has been like *deja vu* all over again for me. Fifteen years ago, one of the hardest things to do was not to develop the initial version of HTTP, or to create a browser that was also an editor, or even to get approval for the purchase of the equipment (!). The difficult thing was to convince people that the Web was something they should adopt.

At CERN, the killer app that got us through the technical barriers (OS, HW, philosophy) was making the phone book available through the Web. In the outside world, beyond lab settings, what helped the Web break through were two simultaneous developments - that CERN was making the code available to anyone who would like it free of charge or other encumbrance, and that young developers were coming up with browser software, including multiple implementations that supported inline images. And so with the potential licensing barriers down and the relative ease of setting up a server, things took off. But imagine, if you can, online information systems before the Web, and what it was like to try to explain the whole idea of the Web to people.

Envisioning life in the Semantic Web is a similar proposition. Some people have said, "Why do I need the Semantic Web? I have Google!" Google is great for helping people find things, yes! But finding things more easily is not the same thing as using the Semantic Web. *It's about creating things from data you've compiled yourself, or combining it with volumes (think databases, not so much individual documents) of data from other sources to make new discoveries.* It's about the ability to use and reuse vast volumes of data. Yes, Google can claim to index billions of pages, but given the format of those diverse pages, there may not be a whole lot more the search engine tool can reliably do. We're looking at applications that enable transformations, by being able to take large amounts of data and be able to run models on the fly - whether these are financial models for oil futures, discovering the synergies between biology and chemistry researchers in the Life Sciences, or getting the best price and service on a new pair of hiking boots.

I. Vision Questions

CSB: *Did you consider other ways of taking the next step to evolve the Web besides the semantic approach? If so, what were they?*

TBL: You mean, if we don't have data on the web, would there be other interesting things? Of course, but they wouldn't replace it. And we do have lots of other things happening. The Mobile Web Initiative -- just launched -- is about making it easy to make web sites which work on mobile devices. There's Web Services, about integration of programs across organizational and application boundaries.

It's a bit like asking, if we didn't have graphics, on the web, would we have other interesting things? Well, we would -- but not graphics. The Semantic Web gives you an especially powerful form of data integration. It does this by using URIs, and by connecting your raw data (in databases, XML documents, etc) to a model of the real things (like customers, products, etc.) which your business uses. Any system which does one without the other won't get the effect of allowing data from one application to be used in unexpected new ways by other applications. And any system which does the same thing but doesn't use the common standards isn't going to be compatible, and so isn't going to be part of it.

CSB: *What are the limitations of the Semantic Web – what will it enable someone to do, and what will it not permit us to do?*

TBL: The goal of the Semantic Web initiative is to create a universal medium for the exchange of data where data can be shared and processed by automated tools as well as by people. The Semantic Web is designed to smoothly interconnect personal information management, enterprise application integration, and the global sharing of commercial, scientific and cultural data. We are talking about data here, not human documents.

The Semantic Web is not about the meaning of English documents. It's not about marking up existing HTML documents to let a computer understand what they say. It's not about the artificial intelligence areas of machine learning or natural language understanding -- they use the word *semantics* with a different meaning.

It is about the data which currently is in relational databases, XML documents, spreadsheets, and proprietary format data files, and all of which would be useful to have access to as one huge database.

CSB: *What sorts of technical or other constraints led you to adopt the particular semantic approach you adopted?*

TBL: Building upon the Web architecture was an important technical constraint in the design and development of Semantic Web standards. The Semantic Web is about Web evolution, not revolution. Our focus on building the standards was to layer this work upon the existing Web infrastructure to create both a Web of Documents and Data. While this may be seen as a limitation, I believe it has been beneficial on the whole.

CSB: *Some commentators, such as Kim Veltman in "Towards a Semantic Web for Culture" <<http://jodi.tamu.edu/Articles/v04/i04/Veltman/>> have been critical of the limited degree of cultural context that the current design of the Semantic Web could comprehend. Do you believe that it would be technically feasible in the future to accommodate such goals, and if so, would the Semantic Web be an appropriate platform from which to take such a next step?*

TBL: The paper you refer to talks about the subtleties of the meaning of words in our natural languages, and how these change with evolving cultures. While an interesting study, it is not the domain of the Semantic Web.

CSB: *As you look at the Semantic Web project now, some 8 years after its inception, are you encouraged or discouraged? Does it look to you today as if you will be able to accomplish less, as much, or more than you had originally envisioned?*

TBL: The Semantic Web has a whole lot more to it than the original Web. Building something which will be a firm logical foundation for interoperating business systems and query systems and so on takes more work and has to be a lot more well defined than a simple jotting down of some HTML tags! However, we have the entire URI and HTTP infrastructure to build on, of course.

One can always wish things were further along, but in fact I think the progress has been great. We were asked to hold up the query and rules work because people didn't want to start on it until the ontology (OWL) work had finished, so for some we were in danger of going too fast. Now we have a good solid layer of RDF and OWL which allows systems to be described, and data to be exchanged. OWL turned out to be more powerful than I had expected (I had expected something more like RDFS++) and that is great. The query language I think will be a major step, as it will allow major databases to be exposed without one having to transfer the whole file. It will also provide a way of integrating across SQL and XQuery systems.

I'm disappointed that we haven't seen RDF used as an export format on random applications such as desktop and enterprise applications. This may be because the RDF/XML syntax is a little off-putting. It is an irony that the RDF model itself is simpler than that of XML, but it isn't evident when you encode it in the standard syntax. The informal N3 syntax provides a learning and more human-friendly on-ramp for

export and import, and it may be that standardizing that would be a useful step. On the other hand, there is an ever-growing set of adapters from various formats to RDF.

I am very happy about the reception which the Semantic Web has had in specific areas where people "get it". The FOAF project, for example, has a great spirit, and is a quite decentralized web of information about people's business cards, CVs, and who knows who. The whole area of life sciences and healthcare has been hopping with excitement as work is done to take down the boundaries between different silos of information across the field. We had a very vibrant workshop in the area, and Semantic Web was the talk of the recent BIO-IT conference.

I think the hope for more true interactivity in terms of collaborative tools, particularly real-time collaborative tools, has yet to be realized – it's something I had hoped for in the early days, and I am still hoping to see it happen.

CSB: *Since this is your second time around designing the Web, what did you learn from taking the Web from concept to reality the first time that may help us anticipate how the Semantic Web will become real?*

TBL: The Semantic Web idea -- that of having data as well as documents on the web -- has been around since the start of the web. It is just more complicated to do. Experience from the initial growth of the web of documents? Well, it was a very rigid exponential growth, which couldn't be slowed or hastened. Different people 'got it' in different years, and to them it's seemed that the web had 'happened' all that year. It spread first among enthusiasts, and then among small sub-communities where one could get to critical mass with the momentum of a few champions. These communities (High Energy Physics for the WWW, possibly Life Sciences for Semantic Web) are full of people who have very big challenges to tackle, and are largely scientifically minded people who understand the new paradigm. These things may be very similar.

Where it is different is that there is attention from the press. We work under floodlights. Whereas the WWW took off in the hands of the converts, and others were left in blissful ignorance, the SW takes off with articles like this one, and people checking to see whether it is time for them to get involved. This has helped in some ways, hindered in others. We have to work hard to make sure that expectations are not overstated.

I think there were important landmarks in getting the Web broadly adopted. The fact that CERN would not impose onerous licensing conditions on the use of Web technologies cannot be overstated. I knew of companies – big companies – that forbade their employees to pick up our work until CERN made its declaration for free use. The W3C patent policy now makes the development of new standards much safer in this respect, and it is an important aspect of the Semantic Web that it be royalty free.

CSB: *What would you like to see happen as the next step after the Semantic Web becomes a reality? Will the W3C be the place for that to happen?*

TBL: The Web will continue to evolve and adapt and the Semantic Web is part of this evolution. As the Semantic Web becomes more pervasive, I expect new challenges will be addressed in terms of usability, accessibility along with the application of these technologies in a variety of new domains: mobile, scientific, cultural, etc.

Just as the big search engines, and the clever algorithms which drive them, could not be designed when the WWW was young, so there will be applications the need for which is only evident when we have a large scaled Semantic Web. These may involve the creation of new standards.

CSB: *Who should be excited about the Semantic Web that is not perhaps realizing yet what it could mean to them?*

TBL: Many large-scale benefits are, not surprisingly, evident for enterprise level applications. The benefits of being able to reuse and repurpose information inside the enterprise include both for savings and new discoveries. And of course, more usable data brings about a new wave of software development for data analysis, visualization, smart catalogues... not to mention new applications development. The

point of the Semantic Web is in the potential for new uses of data on the Web, much of which we haven't discovered yet.

II. Status Questions

CSB: *The February 10, 2004 OWL/RFD press release stated: "Today's announcement marks the emergence of the Semantic Web as a broad-based, commercial-grade platform for data on the Web. The deployment of these standards in commercial products and services signals the transition of Semantic Web technology from what was largely a research and advanced development project over the last five years, to more practical technology deployed in mass market tools that enables more flexible access to structured data on the Web." <www.w3.org/2004/01/sws-pressrelease> Did that mean that you expected people to start encoding Webpages semantically from that point forward? Have they?*

TBL: It's not about people encoding web pages; it's about applications generating machine-readable data on an entirely different scale. Were the Semantic Web to be enacted on a page-by-page basis in this era of fully functional databases and content management systems on the Web, we would never get there. What is happening is that more applications – authoring tools, database technologies, and enterprise-level applications – are using the initial W3C Semantic Web standards for description (RDF) and ontologies (OWL).

CSB: *If it's too soon to expect people to start investing in the Semantic Web, what is the release schedule for the remaining standards needed to "base enable" the Semantic Web? In other words, when is it reasonable for site owners to start investing the time and effort to encode semantics into their webpages?*

TBL: No time like the present. Getting data into Semantic Web-friendly formats is the very first step in the Semantic Web progression, but you correctly note that there are layers to go – for Rules, Query languages, logic and proof – that are part of that full stack. You can see a quick diagram at: <www.w3.org/2003/Talks/05-gartner-tbl/slide29-0.html>

III. Critics

CSB: *Not surprisingly for as complex and ambitious a project as this, there have been critics of the Semantic Web initiative. Which of their criticisms do you think are valid, and which invalid?*

TBL: W3C has over 20 different Activities, all of which have Member support. The Semantic Web activity is one of them, and one of the few that gets the bulk of its operating costs from outside sources. (The well-regarded Web Accessibility Initiative has many outside sponsors from government and industry, and the new Mobile Web Initiative is building its budget on a separate fee structure.

One of the criticisms I hear most often is, "The Semantic Web doesn't do anything for me I can't do with XML". This is a typical response of someone who is very used to programming things in XML, and never has tried to integrate things across large expanses of an organization, at short notice, with no further programming. One IT professional who made that comment around four years ago, said a year ago words to the effect, "After spending three years organizing my XML until I had a heap of home-made programs to keep track of the relationships between different schemas, I suddenly realized why RDF had been designed. Now I used RDF and its all so simple -- but if I hadn't have had three years of XML hell, I wouldn't ever have understood."

Many of the criticisms of the Semantic Web seems (to me at least!) the result of not having understood the philosophy of how it works. A critical part, perhaps not obvious from the specs, is the way different communities of practice develop independently, bottom up, and then can connect link by link, like patches sewn together at the edges. So some criticize the Semantic Web for being a (clearly impossible) attempt to make a complete top-down ontology of everything.

Others criticize the Semantic Web because they think that everything in the whole Semantic Web will have to be consistent, which is of course impossible. In fact, the only things I need to be consistent are the bits of the Semantic Web I am using to solve my current problem.

The web-like nature of the Semantic Web sometimes comes under criticism. People want to treat it as a big XML document tree so that they can use XML tools on it, when in fact it is a web, not a tree. A semantic tree just doesn't scale, because each person would have their own view of where the root would have to be, and which way the sap should flow in each branch. Only webs can be merged together in arbitrary ways.

I think I agree with criticisms of the RDF/XML syntax that it isn't very easy to read. This raises the entry threshold. That's why we wrote N3 and the N3 tutorial, to get newcomers on board with the simplicity of the concepts, without the complexity of that serialization.

CSB: *Does the Semantic Web have any enemies? If so, what are they doing to get in the way, and what is the strategy for dealing with this opposition? For example, will the Semantic Web provide opportunities to the major browsers, or will it threaten their hegemony? And can the Semantic Web succeed without them?*

TBL: The SW is not at all a threat to existing browsers. Remember that this is adding something to the WWW, not replacing it. The existence of data on the web will not threaten the documents, music pictures, and so on... on the Web.

With the standardization and deployment of Semantic Web standards in various commercial products and services, a shift occurred from the perspective of many that this work was research to a recognition that this is a practical technology deployed in mass-market tools that enables more flexible access to structured data on the Web.

I do expect there to be a serious first mover advantage when it comes to being Semantic Web compatible in software products. Data handling software which does not plug into the RDF data bus will be at a serious disadvantage when customers start to protect themselves by demanding SW compatibility.

IV. Business Reality Questions

CSB: *What is the biggest challenge facing realization of the Semantic Web? Is it possible that the standards will be created, but not implemented, or that content owners will never encode semantically in sufficient numbers to make the Semantic Web initiative successful?*

TBL: We've done a great job at establishing sound foundations for description (RDF) and for ontologies (OWL). We've seen significant interest and uptake in the Life Sciences community for the power that the Semantic Web can bring, and have seen successful Semantic Web projects at the National Cancer Institute, as one example.

It is very important to realize that the Semantic Web does not require content owners to individually encode information! The vast bulk of data to be on the Semantic Web is already sitting in databases -- and files in proprietary data formats. Downloaded bank statements, weather and stock quote information, human resource information, geospatial data, maps, and so on...all that is needed to write an adapter to convert a particular format into RDF and all the content in that format is available.

CSB: *People talk about a "Killer App" for the Semantic Web, and you rightly point out that the Semantic Web itself is the Killer App. Still, there has to be an incentive for people to encode semantically and create agents, so there seems to at least be a chicken and egg issue. Does a company like Google have to commit to semantic browsing before the Semantic Web takes off?*

TBL: I think that for many companies it may be that the killer app is an intranet. Many of the early WWW servers were inside the firewalls. The valuable data is company-confidential, and it is much safer to experiment with new technology in private! One computer company had, I think, 100 web servers internally before it had a public one. Similarly now, pharmaceutical companies are experimenting

internally, but the company data isn't all shared. This slows uptake, as the results are not there to be linked to by others. Similarly, when I do my personal finances using Semantic Web tools, I can export the rule files -- but not the data as an example!

Note that search engines for the traditional web of documents have the task of finding relevant items in a sea of documents in (some form of more or less broken) natural language, with links. The Semantic Web is very different. Search techniques for the Semantic Web are going to be very different: it may be that the value add will be made in different ways by systems roaming around and looking for patterns, or by performing some specific types of inference, or by indexing Semantic Web data in new interesting ways. It probably won't be eigenvector-based link analysis which drives the good hypertext search engines. In a way, the search engines are making up, by special techniques, for the lack of machine-understandable semantics in the documents on the web.

CSB: *If buy-in by the search engines is crucial, where do Google, Yahoo, MSN (or other candidates to fill this role) stand on the Semantic Web?*

TBL: Of these, I know that Yahoo has implemented a Search feature based on Creative Commons' work, which uses RDF to describe licensing terms on Web content: <<http://search.yahoo.com/cc>>

CSB: *If the big browser companies do not come on board, what will be the value proposition that will drive semantic encoding?*

TBL: The Semantic Web architecture does not involve HTML browsers as we know them. There is a new breed of generic Semantic Web browser, but they are more like unconstrained database viewing applications than hypertext browsers.

There are at least two Semantic Browser projects I know of at MIT alone.

SIMILE <<http://simile.mit.edu/>> is a joint project conducted by the W3C, HP, MIT Libraries, and MIT CSAIL. SIMILE seeks to enhance inter-operability among digital assets, schemata/vocabularies/ontologies, metadata, and services. A key challenge is that the collections which must inter-operate are often distributed across individual, community, and institutional stores. To in part address this goal, the SIMILE team created Piggy Bank as an extension to the Firefox web browser that turns it into Semantic Web browser, letting you make use of existing information on the Web in more useful and flexible ways.

The Haystack Project <<http://haystack.lcs.mit.edu/>> is investigating approaches designed to let people manage their information in ways that make the most sense to them. By removing arbitrary application-created barriers, which handle only certain information "types" and relationships as defined by the developer, we aim to let users define their most effective arrangements and connections between views of information. Such personalization of information management will dramatically improve everyone's ability to find what they need when they need it. This includes Piggybank as well as what they call the universal information client.

CSB: *Who do you expect the early adopters to be, on the encoding side? Are there some there already?*

TBL: Adobe is the only one I can talk about today, but there are others on the cusp of announcement.

CSB: *Are specialized agents essential for the Semantic Web, or would adoption of semantic search capability by the Googles of the world be enough?*

TBL: I think you're likely to see both.

CSB: *What will the Semantic Web do to browsers? Will it be likely to strengthen the influence of the major browsers, or result in new entrants?*

TBL: I think you'll see a bit of both here as well - revitalization of competition, and clear targets for functionality, but it's a bit complicated. In short, browsers will be affected by the Semantic Web in many ways.

They may be pressured to become generic Semantic Web browsers. They may use Semantic Web metadata to accompany the human-oriented media. They may use Semantic Web metadata to select and marshal human-oriented metadata. There may be a very powerful client-side programming platform developed (as in Haystack, and RDF-Ajax applications) in which the client-side script sees the world and the display medium as a mass of RDF and SPARQL.

CSB: *Do you believe that semantic encoding will become ubiquitous quickly, or will there be a two-layer Web for a long period of time (or perhaps permanently)?*

TBL: It's not as if every page on the Web will be retrofitted with Semantic information. What we are likely to see though, is the wrapping of existing data stores, such as data in relational databases. We could anticipate a "View Data" feature in much the same way some of us "View Source". It's also worth noting that the new work in XHTML 2 is looking to include RDF capabilities.

There will always be on the web documents to be processed by people, and data to be processed mainly by machines. This is a feature, not a bug.

CSB: *How much of semantic encoding can be automated?*

TBL: Virtually all. This is like asking how much encoding of spreadsheet data is automated. Eh? These are data systems, not human writing systems. The data is all data, the encoding can only be automatic.

V. Infrastructure Questions

CSB: *Are there standards that will logically be needed to reap the full potential of the Semantic Web that the W3C will not be appropriate to create, and if so, what purpose will they play?*

TBL: There are dozens of organizations out there who are interested in developing their own ontologies, just as there continues to be demand for industry-specific XML vocabularies, on an even larger scale. W3C has recently announced the launch of an Incubator Activity, in which groups that have ideas that are good ones, but usually outside of the W3C purview – think of the development of a specific ontology, for example – can have space at W3C to discuss and develop their idea more fully.

I think it's also important to note that great ideas can develop anywhere, in a variety of organizations. Our hope is that people who decide they want to grow an infrastructure piece of the Semantic Web will come to W3C.

CSB: *Which organizations, logically, would create them?*

TBL: Initially, it is wise to keep the Semantic Web developer community well in touch with itself, and the W3C is the center of that community. However, when the number of ontologies being built grows to become difficult to track, it will be essential for scaling reasons for the development work to move to organizations for specific fields. There is a bit of an analogy with XML, as the XML core and also early applications such as MathML were developed at W3C, but now XML schemas are developed all over the world where the needs are found.

CSB: *Are these other organizations already engaged in that process, and do they see things the same way?*

TBL: At this point, we do not have explicit dependencies on other organizations, though it could happen in the future. However, W3C is primarily focused on Web infrastructure, and in the case of Semantic Web, the Semantic Web infrastructure. Looking at the stack, it's clear that some of the boxes have yet to be fleshed out. I think we will have diverse communities coming together to contribute their ideas and directions to the development of each of those components.

A practical example is the case of Rule Languages. They've been around for years – think business rules, or Prolog – but there has yet to be a sweeping dominant rule language standard, much less one that

works on the Web. We recently held a Rules Workshop, and the first day was filled with people presenting their different ideas on Rules – in some cases, they might have been speaking different languages without an interpreter. On the second day, though, these diverse people were able to establish some significant common understandings through the discussion of use cases.

And I think the smaller orgs that focus on single markup languages, coupled with diverse users under the W3C umbrella is a great way to get these technologies developed.

There's no stovepiping at W3C, and there are interoperability requirements that are firm – so we can be sure that if we take up a Rule Languages Working Group, it will have to work with, RDF, OWL, URIs, the Web architecture as it has been articulated at W3C.

CSB: *Are there other technical trends or architectural goals in the evolving Internet and Web landscape that are working against achieving the Semantic Web, or is it still a clear playing field for you to work upon?*

TBL: Vendors have limited resources in much the same ways their customers do, and so if they have committed enormous resources to things that are not Semantic Web, they have little room to move. But even here, we're seeing a shift.

CSB: *What will the use of agents querying for semantic data do to Web search speeds? Will it place additional demands on infrastructure?*

TBL: The kinds of searches we'll be seeing may not be quite the same kind of searches we're used to doing today - in fact, I think we'll see more automation integrated into "search" type applications. We're also at a point where CPUs are not the obstacle, given their price and availability.

VI. User Questions

CSB: *What would a browser that was optimized for the Semantic Web look like?*

TBL: The Semantic Web is in use today behind several data aggregation sites providing richer and more expressive means if integrating data and delivering content. A simple example of a browser that would be optimized for the Semantic Web would allow one to "view data" that might be associated with any of these services and provide the means for save, reuse and integrating this in a variety of other ways with other applications. If one is attending a meeting, or booking an airline reservation, one could simply 'save' this information and drag this onto a calendaring application rather than the tedious effort of cutting and pasting. There is an entirely new set of applications we could imagine, with the only limiting factor being our imagination.

CSB: *When will Web users begin to enjoy the benefits of the Semantic Web?*

TBL: They already have, in applications that range from social networking (FOAF), content description (Adobe Creative Suite), learning about licensing constraints of Web content (Creative Commons), as well as the widespread use of OWL in a variety of disciplines.

To learn more about the Semantic Web, see:

For the W3C Web Standards Activity Page (with links to the Semantic Web Activity Statement, Recommendations [approved standards], News and Events, Presentations, and much more), see:
<<http://www.w3.org/2001/sw/>>

For a detailed description of the technical basis for the Semantic Web and what it will make possible, see:
The Semantic Web, Scientific American, May, 2001:
<www.scientificamerican.com/article.cfm?articleID=00048144-10D2-1C70-84A9809EC588EF21&catID=2>

The early vision (Tim Berners-Lee, September, 1998):

- *Semantic Web Road Map*: <www.w3.org/DesignIssues/Semantic.html>
- *What the Semantic Web Can Represent FAQ*: <www.w3.org/DesignIssues/RDFnot.html>

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