Semantic Web Rules for Web Services

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http://ebusiness.mit.edu

Outline of Talk

- Semantic Web overview
- Web Services overview
- Semantic Web Services overview
- Semantic Web Rules
  - RuleML
  - Uses in Semantic Web Services
  - Example: SweetDeal e-contracting
- Early Adopter Areas
  - *Discussion*

The Semantic Web

The 1st generation, the Internet, enabled disparate machines to exchange data.

•The 2nd generation, the World Wide Web, enabled new applications on top of the growing Internet, making enormous amounts of information available, in human-readable form, and allowing a revolution in new applications, environments, and B2C e-commerce.

•The next generation of the net is an "agent-enabled" resource (the "Semantic Web") which makes a huge amount of information available in machine-readable form creating a revolution in new applications, environments, and B2B e-commerce.

…by enabling "agent" communication at a Web-wide scale.

Web is becoming XML → the Semantic Web

- XML (vs. HTML) offers much greater capabilities for structured detailed descriptions that can be processed automatically.
  - Eases application development effort for assimilation of data in inter-enterprise interchange
  - A suite of open standards both current and emerging
  - … including for knowledge-level SEMANTICS
- *Soon, Agents will Talk according to these standards…*
  - ∴ potential to revolutionize *interactivity* in Web marketplaces
    - B2B, …
- HTML itself is becoming XHTML: just a special case of XML

Vision of Evolution: Agents in Knowledge-Based E-Markets

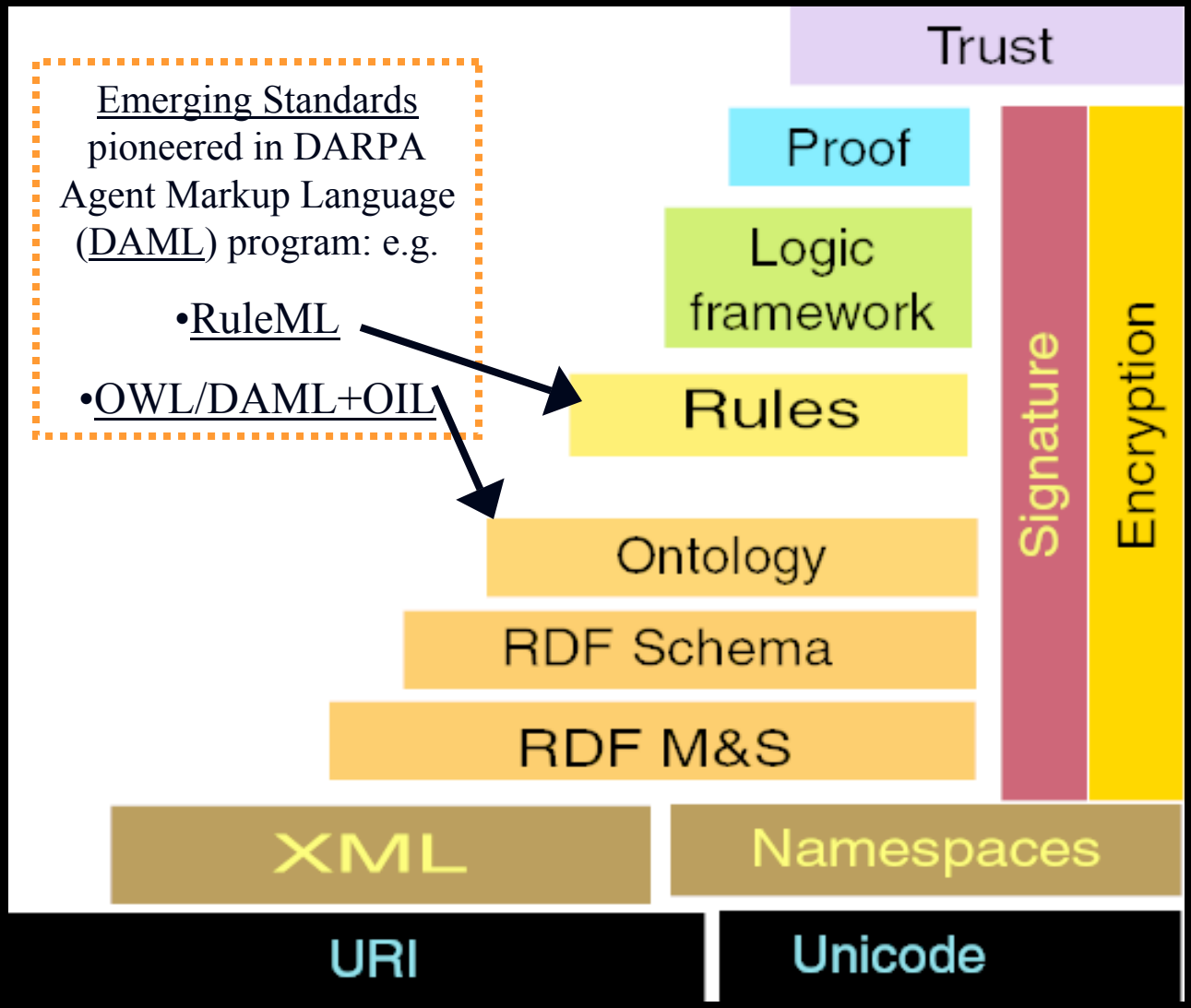
Coming soon to a world near you:…

- billions/trillions of agents (= k-b applications)
- …with smarts: knowledge gathering, reasoning, economic optimization
- …doing our bidding
  - but with some autonomy
- *A 1st step: ability to communicate with sufficiently precise shared meaning… via the SEMANTIC WEB*

SW: Research Players

- US: DARPA Agent Markup Language Program (DAML) program
- EU: OntoWeb program
- @MIT:
  - Sloan IT group: Grosof, Madnick, Firat, Klein, *et al*
  - LCS / W3C advanced-dev.: Berners-Lee, *et al*
- Number of companies:
  - HP, IBM, Adobe, Oracle, …

Semantic Web "Stack": Standardization Steps



[Diagram http://www.w3.org/DesignIssues/diagrams/sw-stack-2002.png is courtesy Tim Berners-Lee]

SW Stack: Acronym Expansion

- W3C = World Wide Web Consortium: umbrella standards body
- XML-S: XML Schema, i.e., basic XML spec
- RDF: Resource Description Framework:
  - W3C Working Group
  - Labelled directed graph syntax
  - Good for building knowledge representation on top of: simpler, more powerful than basic XML
  - M&S = Model and Syntax
  - RDF Schema = extension: simple class hierarchies
- Ontology = formally defined vocabulary & class hierarchy, generalizes Entity-Relationship models
  - OWL = W3C Web Ontologies Working Language
  - … based closely on DAML+OIL

SW: Standards Players

- US-EU Joint Committee:
  - Early standards drafting
  - 1st focus: ontologies: DAML+OIL → W3C OWL
  - 2nd focus (current): rules: RuleML
- W3C: Semantic Web Activity
- Oasis: various incl. Security
- New efforts (currently in formation):
  - US-EU Joint Committee on Semantic Web Services
  - ISO: CommonLogic first-order logic (formerly KIF)

SW-Related: XML Query Languages

- Goals
  - a data model for generic "natively" XML documents,
  - a set of query operators on that data model,
  - and a query language based on these query operators
  - Queries operate on single documents or fixed collections of documents.
- What SQL is for relational databases, XML Query languages are for collections of XML docs.
- There is a standard: W3C's XML Query Working Group
  - (W3C = World Wide Web Consortium)
- Oracle, IBM, Microsoft, etc. already support some
  - Not taking off quickly – complex spec

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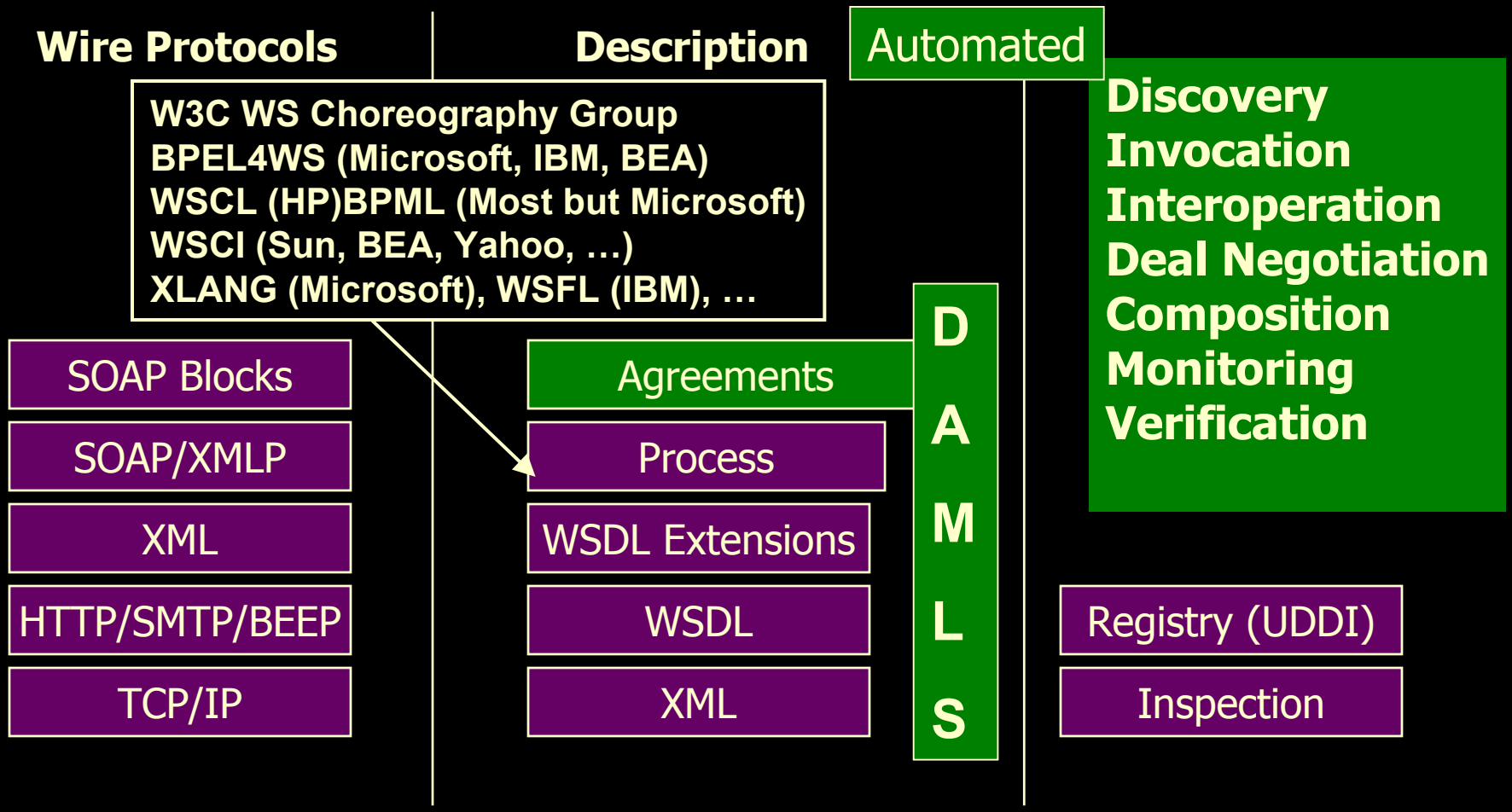
Web Service -- definition

- *(For purposes of this talk:)*

- A procedure/method that is invoked through a Web protocol interface, typically with XML inputs and outputs

Current Web Services Standards Stack; Context for Semantic Web Services



[Modification of slide by James Snell (IBM)]

WS Stack: some Acronym Expansion

- SOAP = simple protocol for XML messaging
- WSDL = protocol for basic invocation of Web Services, their input and output types in XML
- Choreography = higher-level application interaction protocols in terms of sequences of exchanged message types, contingent branching
  - Currently morphing into a W3C activity

- *Overall: lots of proprietary jockeying and de-facto mode testing/pressuring of the open-consortial standards bodies (e.g., of W3C) "riding the tiger"*

WS Players

- Basically, all the major software vendors
  - Biggies: Microsoft, IBM, Oracle, Sun, SAP, …
  - Webserver/XML ebiz space: BEA, CommerceOne, Ariba, …
  - Niche offerings, e.g., travel agent services, weather, …
- Standards bodies: W3C; Oasis incl. Security
- Overall: lots of proprietary jockeying and *de-facto* mode testing/pressuring of the open-consortial standards bodies (e.g., of W3C) "riding the tiger"
- Still low-level in terms of application abstractions

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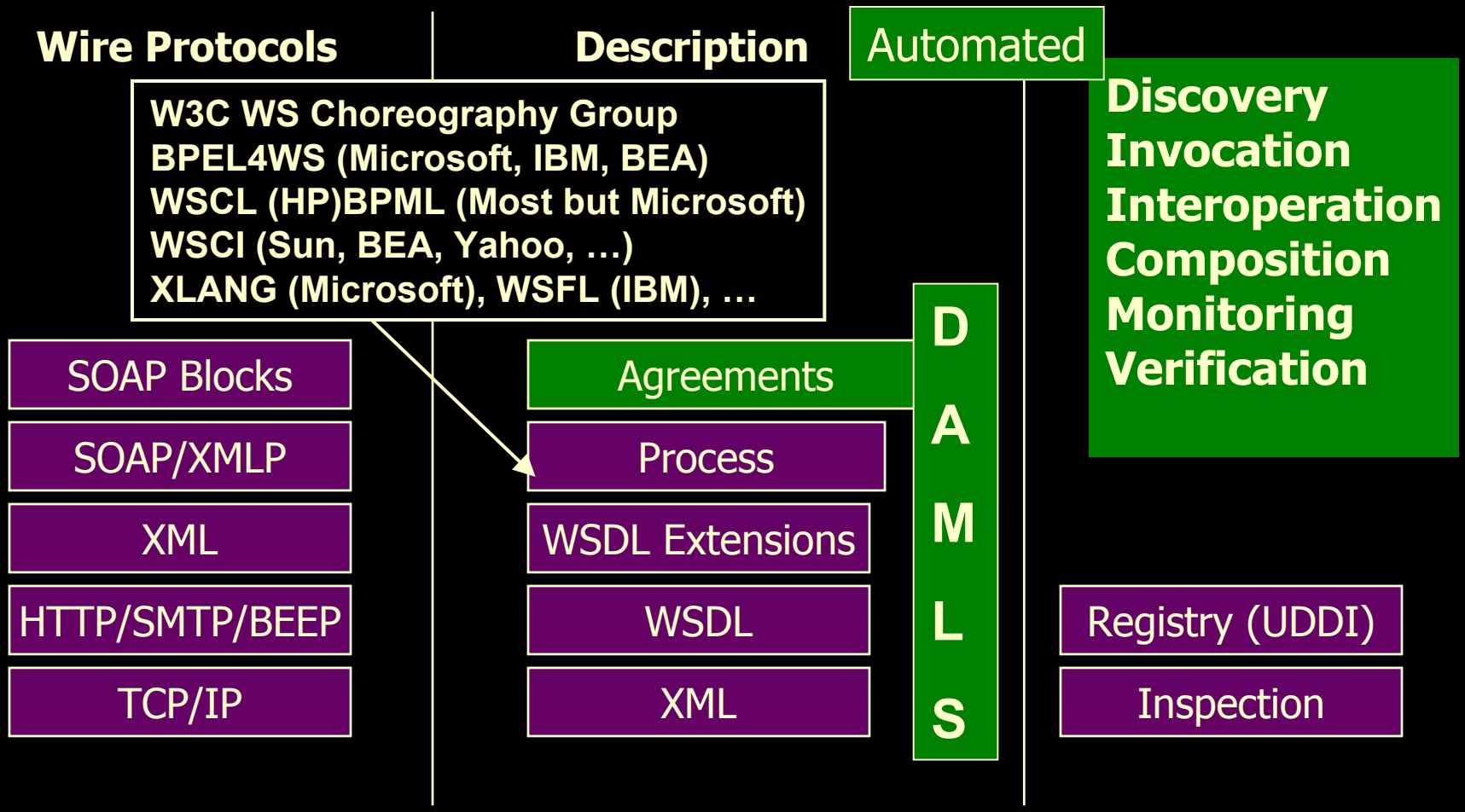
Semantic Web Services

- Convergence of Semantic Web and Web Services
- Consensus definition and conceptualization still forming
- Semantic (Web Services):
  - Knowledge-based service descriptions, deals
    - Discovery/search, invocation, negotiation, selection, composition, execution, monitoring, verification
  - Integrated knowledge
- (Semantic Web) Services: e.g., infrastructural
  - Knowledge/info/DB integration
  - Inferencing and translation

Current Web Services Standards Stack; Context for Semantic Web Services



[Modification of slide also by Sheila McIlraith (Stanford) and David Martin (SRI International), modified from James Snell (IBM)]

SWS Tasks at higher layers of WS stack

Automation of:

- Web service discovery

  Find me a shipping service that will transport frozen vegetables from San Francisco to Tuktoyuktuk.

- Web service invocation

  Buy me "Harry Potter and the Philosopher's Stone" at www.amazon.com

- Web service deals, i.e., contracts, and their negotiation

  Propose a price with shipping details for used Dell laptops to Sue Smith.

- Web service selection, composition and interoperation

  Make the travel arrangements for my WWW11 conference.

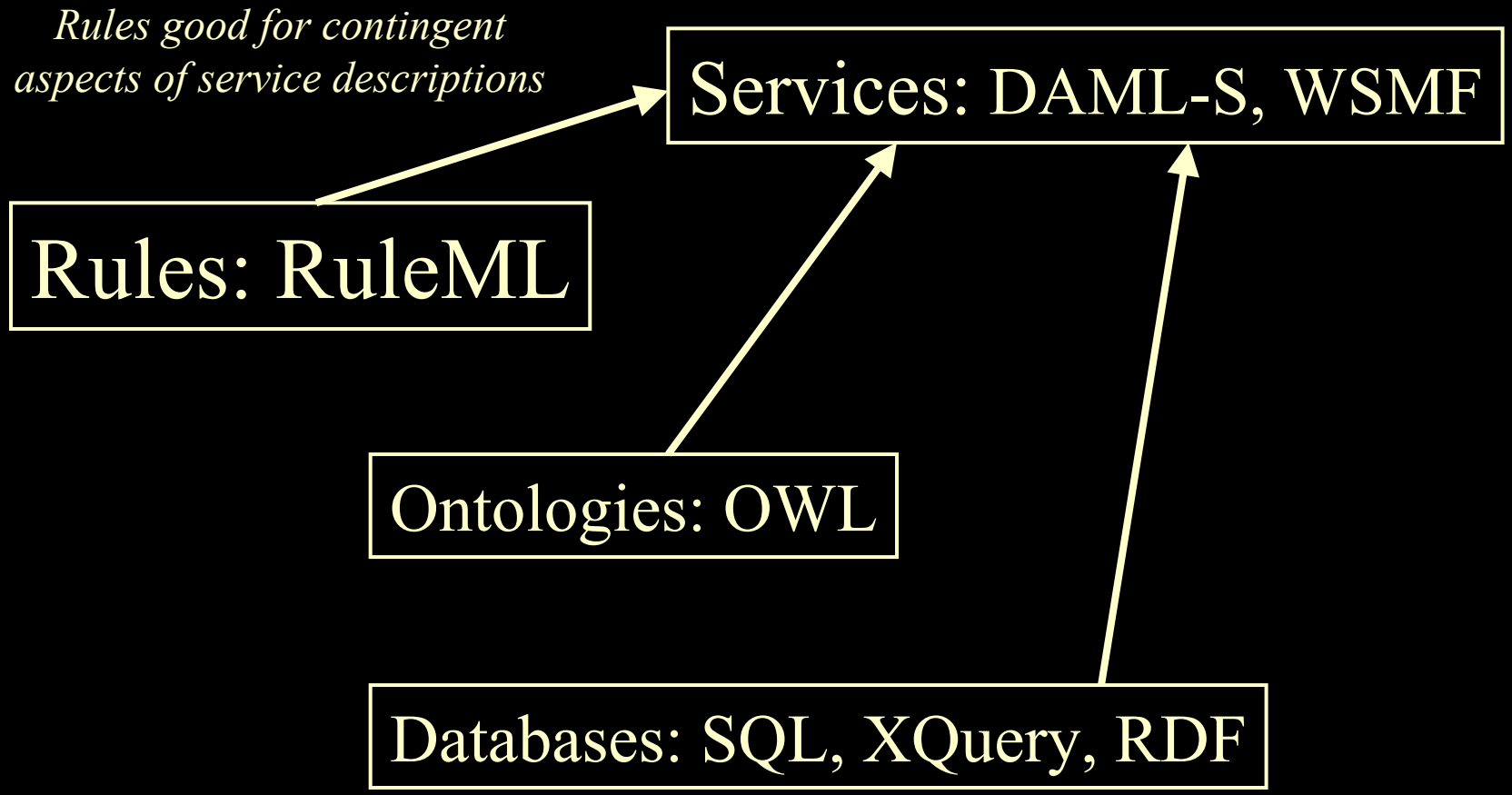
[Modification of slide also by Sheila McIlraith (Stanford) and David Martin (SRI International)]

SWS Tasks at higher layers of WS stack, continued

- Web service execution monitoring and problem resolution
  Has my book been shipped yet? … [NO!] Obtain recourse.
- Web service simulation and verification
  Suppose we had to cancel the order after 2 days?
- Web service executably specified at "knowledge level"
  The service is performed by running the contract ruleset through a rule engine.

[Modification of slide also by Sheila McIlraith (Stanford) and David Martin (SRI International)]

Vision: Semantic Web and Web Services Use DB's, Ontologies, and Rule Systems



SWS: Research Players

- DAML Services (DAML-S)
  - service descriptions using ontologies and now rules
- Web Services Mediator Framework (WSMF)
  - EU, Oracle
  - early phase; list of many companies
- @ MIT: Sloan IT:
  - SweetDeal: e-contracting, policies
  - Extended COIN: financial info integration

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Flavors of Rules Commercially Most Important today in E-Business

- E.g., in OO app's, DB's, workflows.

- Relational databases, SQL: Views, queries, facts are all rules.
  - SQL99 even has recursive rules.
- Production rules (OPS5 heritage): e.g.,
  - Blaze, ILOG, Haley: rule-based Java/C++ objects.
- Event-Condition-Action rules (loose family), cf.:
  - business process automation / workflow tools.
  - active databases; publish-subscribe.
- Prolog. *"logic programs" as a full programming language.*
- *(Lesser: other knowledge-based systems.)*

Vision: Uses of Rules in E-Business

- Rules as an important aspect of coming world of Internet e-business: rule-based business policies & business processes, for B2B & B2C.
  - represent seller's offerings of products & services, capabilities, bids; map offerings from multiple suppliers to common catalog.
  - represent buyer's requests, interests, bids; → matchmaking.
  - represent sales help, customer help, procurement, authorization/trust, brokering, workflow.
  - high level of conceptual abstraction; easier for non-programmers to understand, specify, dynamically modify & merge.
  - executable but can treat as data, separate from code
    - potentially ubiquitous; already wide: e.g., SQL views, queries.
- Rules in communicating applications, e.g., embedded intelligent agents.

Why Standardize Rules Now?

- Rules as a form of KR (knowledge representation) are especially useful:
  - relatively mature from basic research viewpoint
  - good for prescriptive specifications (vs. descriptive)
    - a restricted programming mechanism
  - integrate well into commercially mainstream software engineering, e.g., OO and DB
    - easily embeddable; familiar
    - vendors interested already: Webizing, app. dev. tools
- *⇒⇒ Identified as part of mission of the W3C Semantic Web Activity*

Overview of RuleML Today

- RuleML Initiative (2000--)
  - Dozens of institutions (~35), researchers; esp. in US, EU
  - Mission: Enable semantic exchange of rules/facts between most commercially important rule systems
  - Standards specification: 1st version 2001; basic now fairly stable
  - A number of tools (~12 engines, translators, editors), demo applications
  - Successful Workshop on Rules at ISWC was mostly about RuleML / LP
  - Has now a "home" institutionally in DAML and Joint Committee
    - Discussions well underway to launch W3C, Oasis efforts
- Initial Core: Horn Logic Programs KR

  …Webized (in markup)… and with expressive extensions

  URI's, XML, RDF, ... *non-mon, actions, ...*

Overview of RuleML Today, Continued

- Fully Declarative KR (not simply Prolog!)
  - Well-established logic with model theory
  - Available algorithms, implementations
  - Close connection to relational DB's; core SQL is Horn LP
  - *See [Baral & Gelfond '94] for good survey on declarative LP.*
- Abstract graph syntax
  - 1st encoded in XML…
  - … then RDF (draft), … then DAML+OIL (draft)
- Expressive Extensions incrementally, esp. already:
  - Non-monotonicity: Negation as failure; Courteous priorities
  - Procedural Attachments: Situated actions/effecting, tests/sensing
  - *In-progress:* Events cf. OPS5/Event-Condition-Action

Rule-based Semantic Web Services

- Rules/LP in appropriate combination with DL as KR, for RSWS
  - DL good for categorizing: a service overall, its inputs, its outputs
- Rules to describe service process models
  - rules good for representing:
    - preconditions and postconditions, their contingent relationships
    - contingent behavior/features of the service more generally,
      - e.g., exceptions/problems
  - familiarity and naturalness of rules to software/knowledge engineers
- Rules to specify deals about services: cf. e-contracting.

Rule-based Semantic Web Services

- Rules often good to executably specify service process models
  - e.g., business process automation using procedural attachments to perform side-effectful/state-changing actions ("effectors" triggered by drawing of conclusions)
  - e.g., rules obtain info via procedural attachments ("sensors" test rule conditions)
  - e.g., rules for knowledge translation or inferencing
  - e.g., info services exposing relational DBs
- Infrastructural: rule system functionality as services:
  - e.g., inferencing, translation

Application Scenarios for Rule-based Semantic Web Services

- SweetDeal [Grosof & Poon 2002] configurable reusable e-contracts:
  - LP rules about agent contracts with exception handling
  - … on top of DL ontologies about business processes;
  - *a scenario motivating DLP*

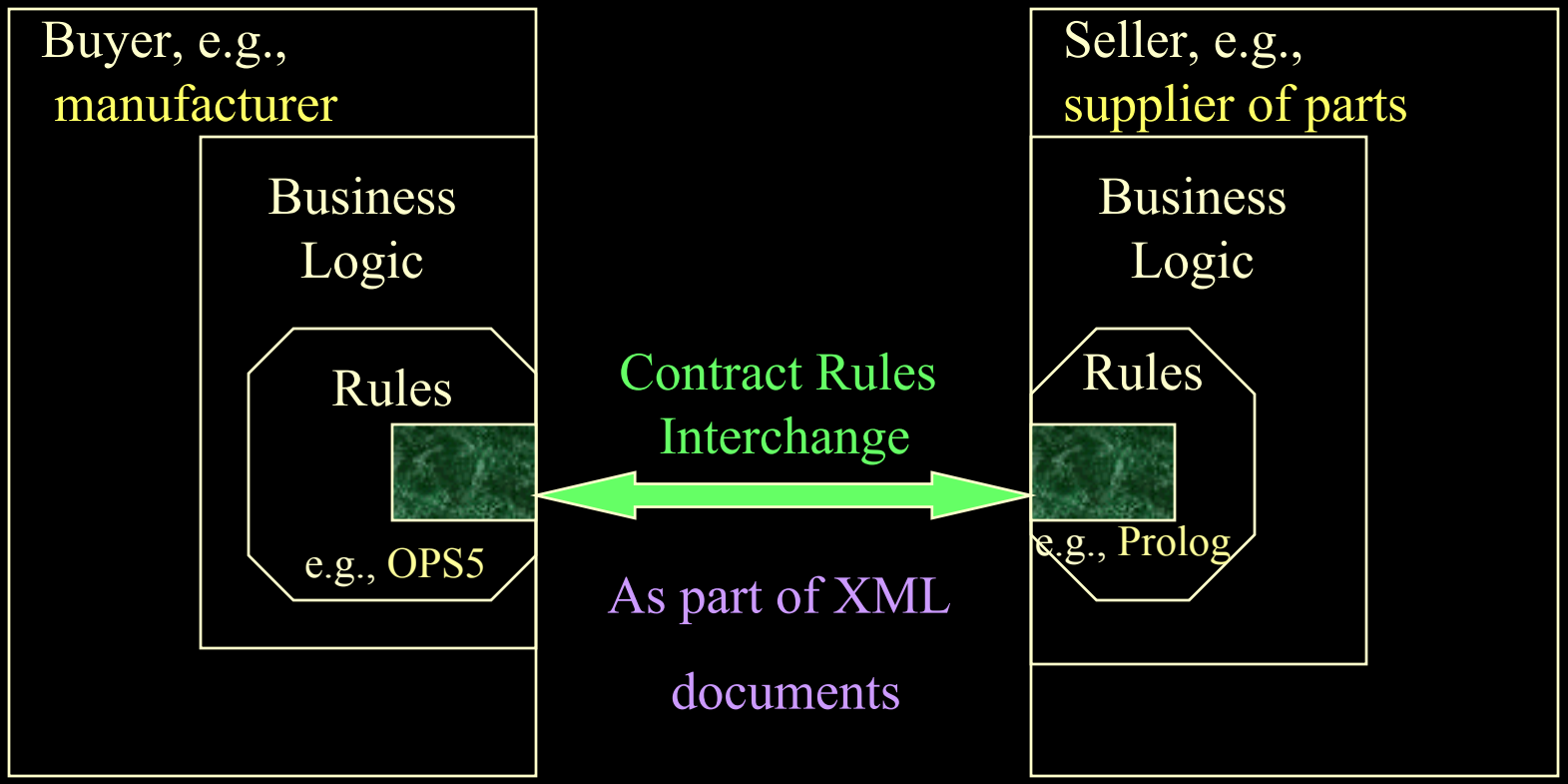
- Other:
  - Trust management / authorization (Delegation Logic) [Li, Grosof, & Feigenbaum 2000]
  - Financial knowledge integration (ECOIN) [Firat, Madnick, & Grosof 2002]
  - Privacy policies (P3P APPEL)
  - Business policies, more generally

Slides on SweetDeal: Pointer

- See talk slides (from ISWC Rules Workshop 2002) at http://ebusiness.mit.edu/bgrosof/#SweetDealExceptions

- Next few slides, taken from that, give a sample.

Contract Rules during Negotiation



Contracting parties NEGOTIATE via shared rules.

Overview I: *SweetDeal, Exception Handlers, Web Services*

- This work is part of **SweetDeal**: rule-based approach for e-contracting
- Advantages of rule-based: (use Situated Courteous LP KR in RuleML)
  - high level of conceptual abstraction to specify; modularly modifiable; reusable; executable
  - esp. good for specifying *contingent* provisions
- Reusable ruleset modules represent parts of contracts
- Here, newly extend to include exception handlers:
  - = violations of commitments → invoke business processes
  - more complex behavior
  - good for services, e.g., **deals about Web services**
  - process descriptions whose ontologies are in DAML+OIL
    - drawn from MIT Process Handbook, a previous repository
      - uniquely large & well-used (by industry biz process designers)
  - partially or fully specified by rules (executably)

Example Contract Proposal with Exception Handling

Represented using RuleML & DAML+OIL, Process Descriptions

Using concise text syntax

(SCLP textfile format)

for concise human reading

```
buyer(co123,acme);
seller(co123,plastics_etc);
product(co123,plastic425);
price(co123,50);
quantity(co123,100);
http://xmlcontracting.org/sd.daml#Contract(co123);
http://xmlcontracting.org/sd.daml#specFor(co123,co123_process);
http://xmlcontracting.org/sd.daml#BuyWithBilateralNegotiation(co123_process);
http://xmlcontracting.org/sd.daml#result(co123,co123_res);
shippingDate(co123,3); // i.e. 3 days after order placed
// base payment = price * quantity
payment(?R,base,?Payment) <-
  http://xmlcontracting.org/sd.daml#result(co123,?R) AND
  price(co123,?P) AND quantity(co123,?Q) AND
  multiply(?P,?Q,?Payment) ;
```

SCLP TextFile Format for (Daml)RuleML

```
payment(?R,base,?Payment) <-
http://xmlcontracting.org/sd.daml#result(co123,?R) AND
price(co123,?P) AND quantity(co123,?Q) AND
multiply(?P,?Q,?Payment) ;
```

```
<drm:imp>
  <drm:_head> <drm:atom>
     <drm:_opr><drm:rel>payment</drm:_opr></drm:rel>    <drm:tup>
     <drm:var>R</drm:var> <drm:ind>base</drm:ind> <drm:var>Payment</drm:var>
  </drm:tup></drm:atom> </drm:_head>
  <drm:_body>
   <drm:andb>
     <drm:atom> <drm:_opr>
       <drm:rel href= "http://xmlcontracting.org/sd.daml#result"/>
         </drm:_opr> <drm:tup>
           <drm:ind>co123</drm:ind> <drm:var>Cust</drm:var>
          </drm:tup> </drm:atom>

... </drm:andb> </drm:_body>  </drm:imp>
```

drm = namespace for damlRuleML

Example Contract Proposal, Continued: lateDeliveryPenalty exception handler module

```
lateDeliveryPenalty_module {
// lateDeliveryPenalty is an instance of PenalizeForContingency
//   (and thus of AvoidException, ExceptionHandler, and Process)
http://xmlcontracting.org/pr.daml#PenalizeForContingency(lateDeliveryPenalty) ;
// lateDeliveryPenalty is intended to avoid exceptions of class
// LateDelivery.
http://xmlcontracting.org/sd.daml#avoidsException(lateDeliveryPenalty,
  http://xmlcontracting.org/pr.daml#LateDelivery);
// penalty = - overdueDays * 200 ; (negative payment by buyer)
<lateDeliveryPenalty_def> payment(?R, contingentPenalty, ?Penalty) <-
  http://xmlcontracting.org/sd.daml#specFor(?CO,?PI) AND
  http://xmlcontracting.org/pr.daml#hasException(?PI,?EI) AND
  http://xmlcontracting.org/pr.daml#isHandledBy(?EI,lateDeliveryPenalty) AND
  http://xmlcontracting.org/sd.daml#result(?CO,?R) AND
  http://xmlcontracting.org/sd.daml#exceptionOccurred(?R,?EI) AND
  shippingDate(?CO,?CODate) AND shippingDate(?R,?RDate) AND
  subtract(?RDate,?CODate,?OverdueDays) AND
  multiply(?OverdueDays, 200, ?Res1) AND multiply(?Res1, -1, ?Penalty) ;
}
<lateDeliveryPenaltyHandlesIt(e1)> // specify lateDeliveryPenalty as a handler for e1
 http://xmlcontracting.org/pr.daml#isHandledBy(e1,lateDeliveryPenalty);
```

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SW Early Adoption Candidates: High-Level View

- "Death. Taxes. Integration."
- Application/Info Integration:
  - Intra-enterprise
    - EAI, M&A; XML infrastructure trend
  - Inter-enterprise
    - E-Commerce: procurement, SCM
  - Combo
    - Business partners, extranet trend

SW Early Adopters: Areas by Industry or Task

- Early SW techniques already in use:
  - e-contracting, supply chain incl. procurement
    - manufacturing, e.g. computer/electronics (RosettaNet), automotive (Covisint),
    - EECOMS pilot (Boeing, IBM, TRW, Baan)
    - office supplies (OBI)
    - retailing: shopbots and salesbots: comparisons, recommendations
    - extensive standards activity: Oasis ebXML, XML eContracts, UN UBL, EDI

SW Early Adopters: Areas by Industry or Task

- *Continued:* Early SW techniques already in use:
  - cyber goods:
    - financial services (rules; onto translation)
    - travel "agency", i.e.: tickets, packages (AI smarts for scheduling)
  - military intelligence (e.g., funded DAML)

SW Early Adopters: Areas by Industry or Task

- Still in research or early standardization, mainly:
  - e-contracting:
    - auctions
    - construction
    - insurance, risk management
    - SME's, spontaneity
    - international
    - distribution
  - authorization and security policies
  - business policies

SW Early Adopters: Areas by Industry or Task

- *Continued:* Still in research or early standardization, mainly:
  - reputations, ratings
  - legal/regulatory: forms, dispute resolution ; Oasis Legal XML
  - computer games: massive multi-player
  - question-answering
  - news filtering, e.g., financial
  - knowledge management
  - advertising
  - bioinformatics, scientific Grid
- Others? ? ? ? ? ?

FOR MORE INFO -- on author's webpage

- At http://ebusiness.mit.edu/bgrosof:
  - Recent SweetDeal paper and talk, from Intl. Sem. Web. Conf. (2002) Workshop on Rules; and earlier papers
    - …/#SweetDealExceptions
  - RuleML Overviews
    - …/#RuleML, esp. 10/29/02 Joint Committee intro talk
  - Description Logic Programs paper and talk (discusses deeper technical approach to combining rules and ontologies)
    - …/#DLP
  - SWS Project overviews
    - …/#Overview and …/#Projects

FOR MORE INFO - resources on SW,WS, SWS

- SWS overview: http://ebusiness.mit.edu/#SWS
- DAML http://www.daml.org ; esp. DAML-S …/services
- WSMF http://informatik.uibk.ac.at/users/c70385/wese/publications.html
- W3C SW: http://www.w3.org/2001/sw -> charter, RDF, WebOnt
- Also at W3C: WSDL, Xquery, …
- Web Services – Interoperability http://www.ws-i.org
- Oasis XML standards body http://www.oasis-open.org
- RuleML main site (major editing in progress): http://www.ruleml.org
- And:
  - XML world: the Cover pages http://xml.coverpages.org
  - A SW community portal http://www.semanticweb.org