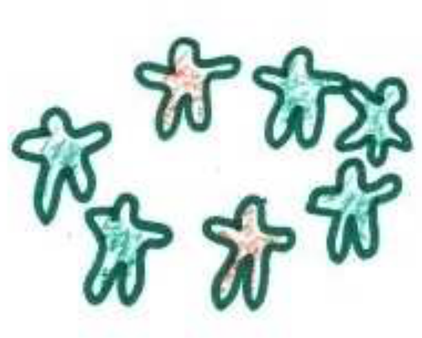
Distributed Governance with Scribble



Beat 2

24th September, 2013

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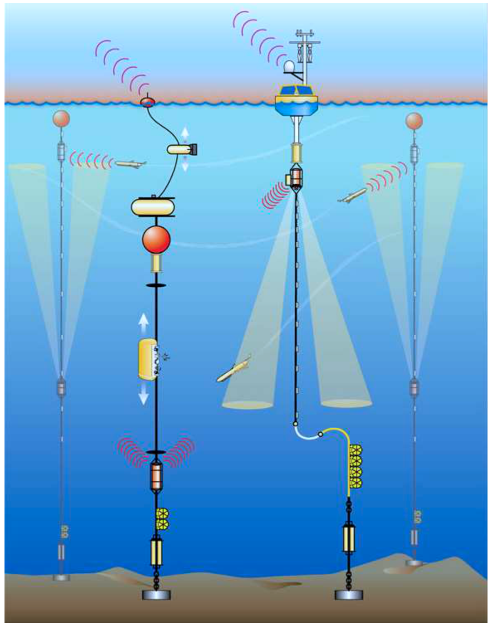
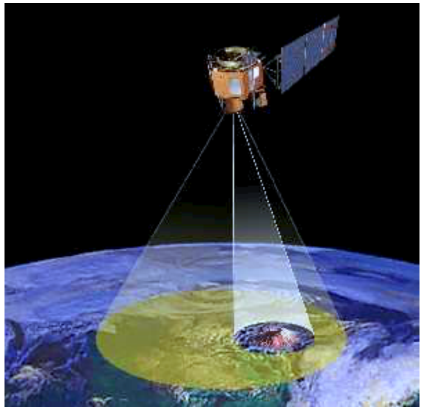
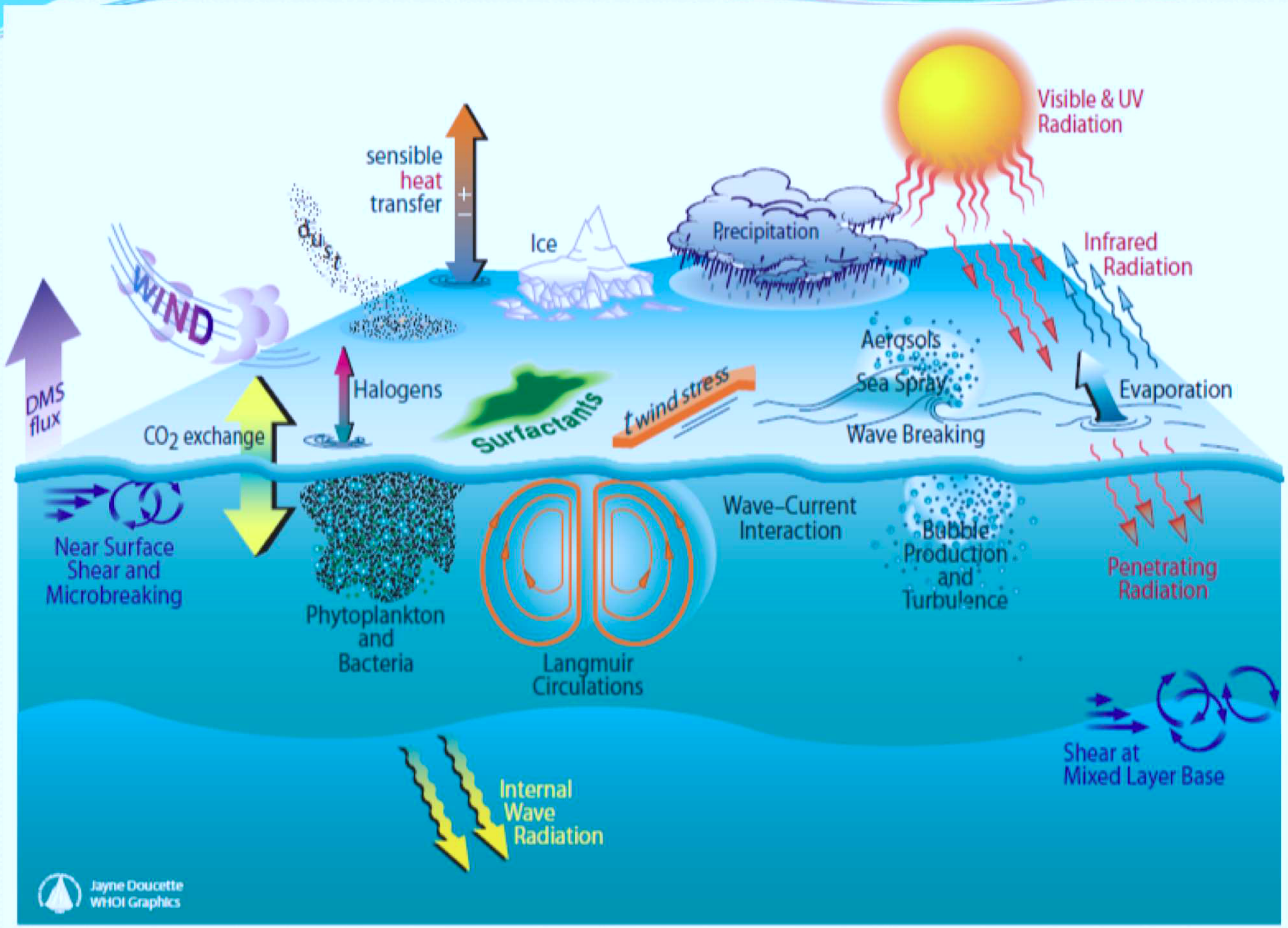
Ocean Observatories Initiative

- A NSF project (400M$, 5 Years) to build a cyberinfrastructure for observing oceans around US and beyond.
- Real-time sensor data constantly coming from both off-shore and on-shore (e.g. buoys, submarines, under-water cameras, satellites), transmitted via high-speed networks.

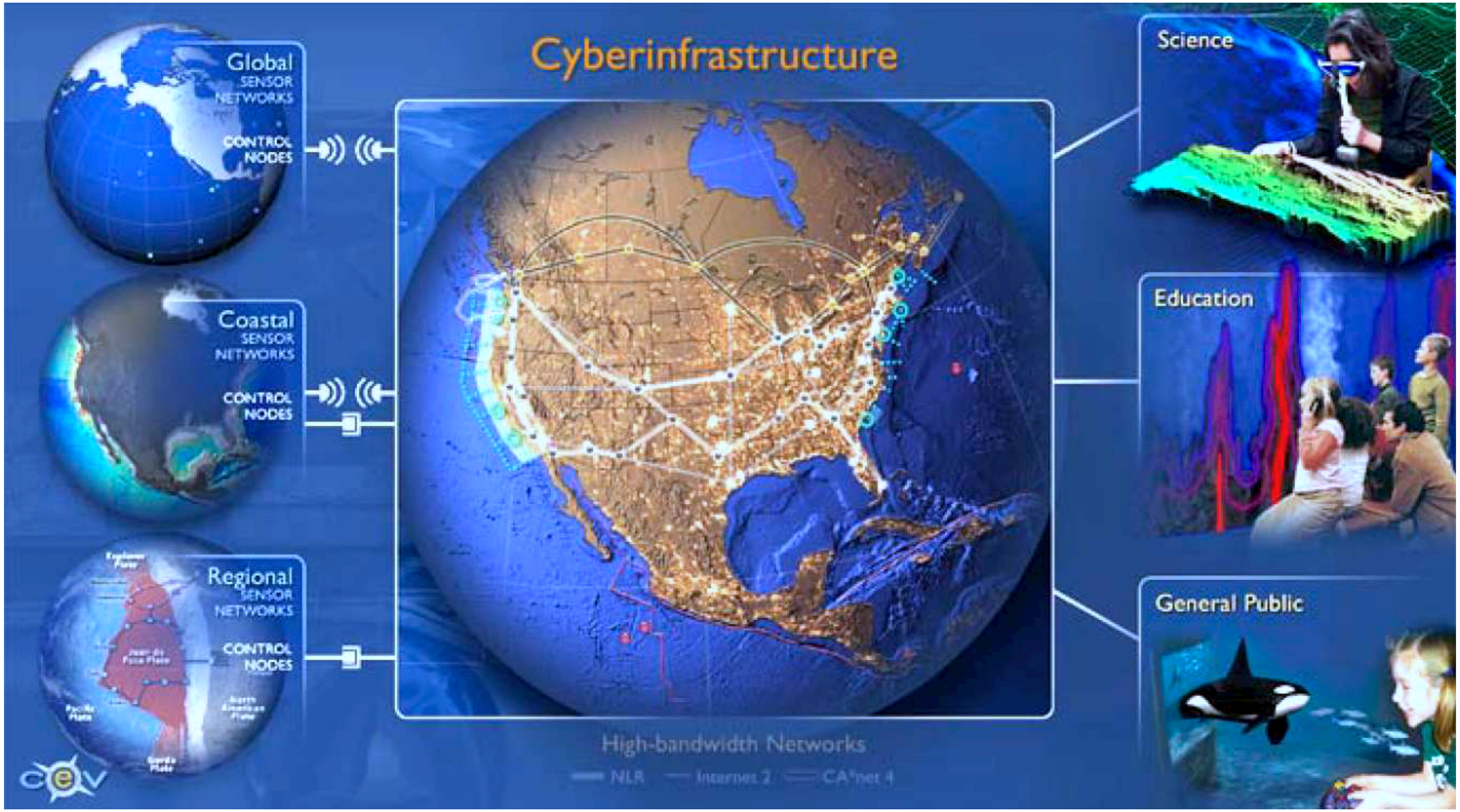


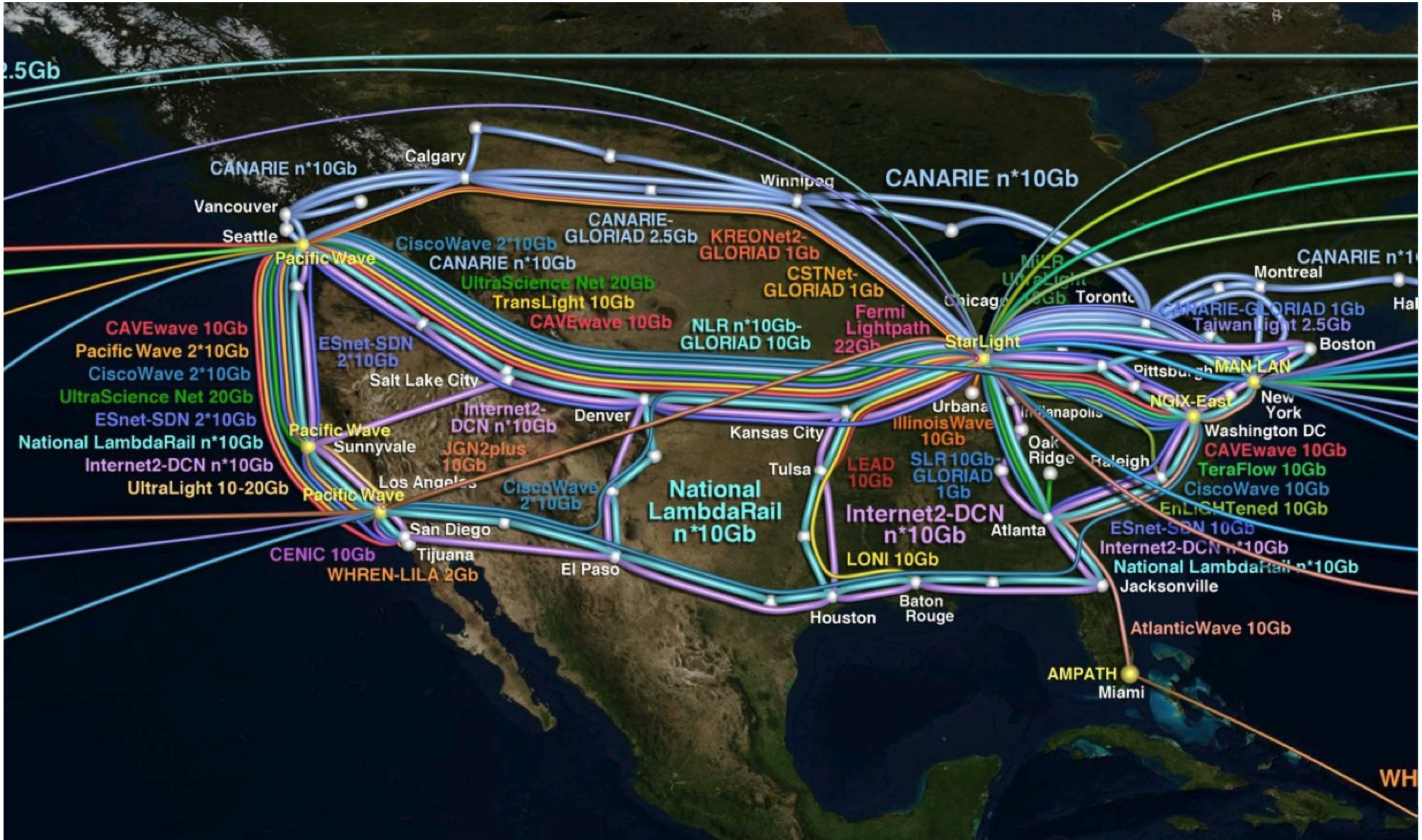




Visible & UV
Radiation
sensible
heat
transfer
dust
Ice
Precipitation
Infrared
Radiation
WIND
DMS
flux
Halogens
Surfactants
wind stress
Aerosols
Sea Spray
Evaporation
CO_2 exchange
Wave Breaking
Wave–Current
Interaction
Near Surface
Shear and
Microbreaking
Bubble
Production
and
Turbulence
Penetrating
Radiation
Phytoplankton
and
Bacteria
Langmuir
Circulations
Shear at
Mixed Layer Base
Internal
Wave
Radiation
Jayne Doucette
WHOI Graphics

Ocean Observatories Initiative





Ocean Observatories Initiative

Challenges

- The need to specify, catalogue, program, implement and manage *multiparty message passing protocols*.
- Communication assurance
  - Correct message ordering and synchronisation
  - Deadlock-freedom, progress and liveness
  - Dynamic message monitoring and recovery
  - Logical constraints on message values
- Shared and used over a long-term period (e.g. 30 years in OOI).

Why Multiparty Session Types?

- Robin Milner (2002): *Types are the leaven of computer programming; they make it digestible*.

  $\Longrightarrow$ Can describe communication protocols as *types*

  $\Longrightarrow$ Can be materialised as *new communications programming languages* and *tool chains*.

- *Scalable* automatic verifications (deadlock-freedom, safety and liveness) without *state-space explosion problems* (*polynomial time complexity*).

- Extendable to *logical verifications* and flexible *dynamic monitoring*.

Dialogue between Industry and Academia

Binary Session Types [PARL'94, ESOP'98]

$\Downarrow$

Milner, Honda and Yoshida joined W3C WS-CDL (2002)

$\Downarrow$

Formalisation of W3C WS-CDL [ESOP'07]

$\Downarrow$

Scribble at π4 Technology

CDL Equivalent

- Basic example:

```
package HelloWorld {
    roleType YouRole, WorldRole;
    participantType You{YouRole}, World{WorldRole};
    relationshipType YouWorldRel between YouRole and WorldRole;
    channelType WorldChannelType with roleType WorldRole;

    choreography Main {
        WorldChannelType worldChannel;

        interaction operation=hello from=YouRole to=WorldRole
                relationship=YouWorldRel channel=worldChannel {
            request messageType=Hello;
        }
    }
}
```

Dr Gary Brown (Pi4 Tech) in 2007

Scribble Protocol

- *"Scribbling is necessary for architects, either physical or computing, since all great ideas of architectural construction come from that unconscious moment, when you do not realise what it is, when there is no concrete shape, only a whisper which is not a whisper, an image which is not an image, somehow it starts to urge you in your mind, in so small a voice but how persistent it is, at that point you start scribbling" - Kohei Honda 2007*

- Basic example:

```
protocol HelloWorld {
    role You, World;
    Hello from You to World;
}
```

Dialogue between Industry and Academia

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$\Downarrow$

Multiparty Session Types [POPL'08]

$\Downarrow$

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⇓

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⇓

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⇓

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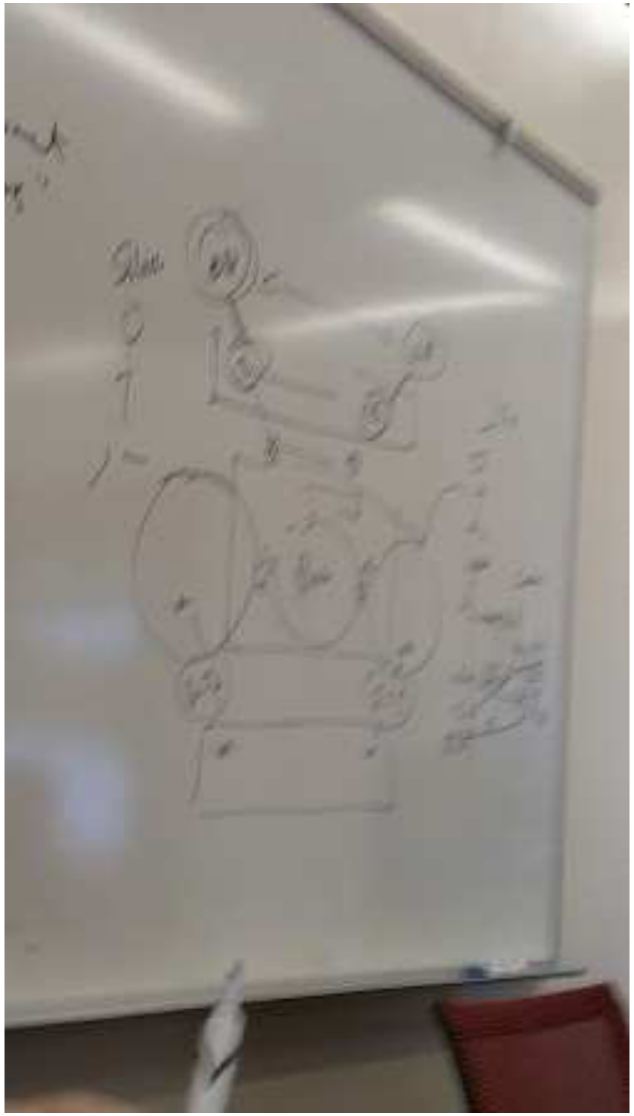
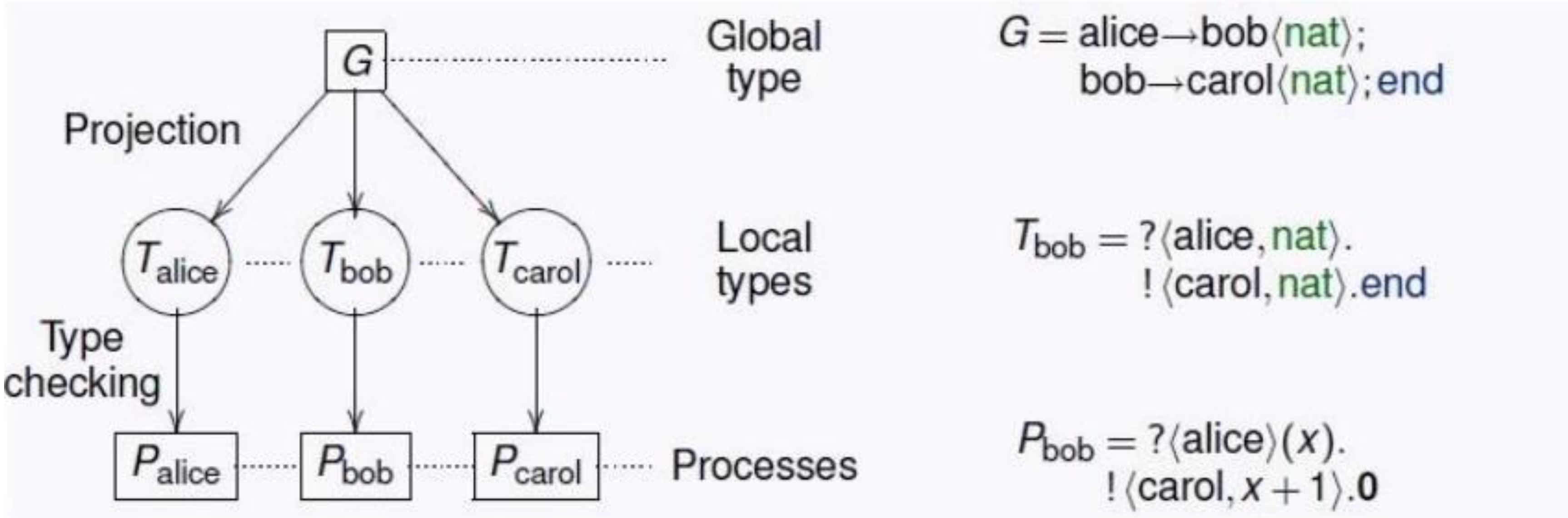
⇓



Session Types Overview



- Properties
  - Communication safety (no communication mismatch)
  - Communication fidelity (the communication follow the protocol)
  - Progress (no deadlock/stuck in a session)

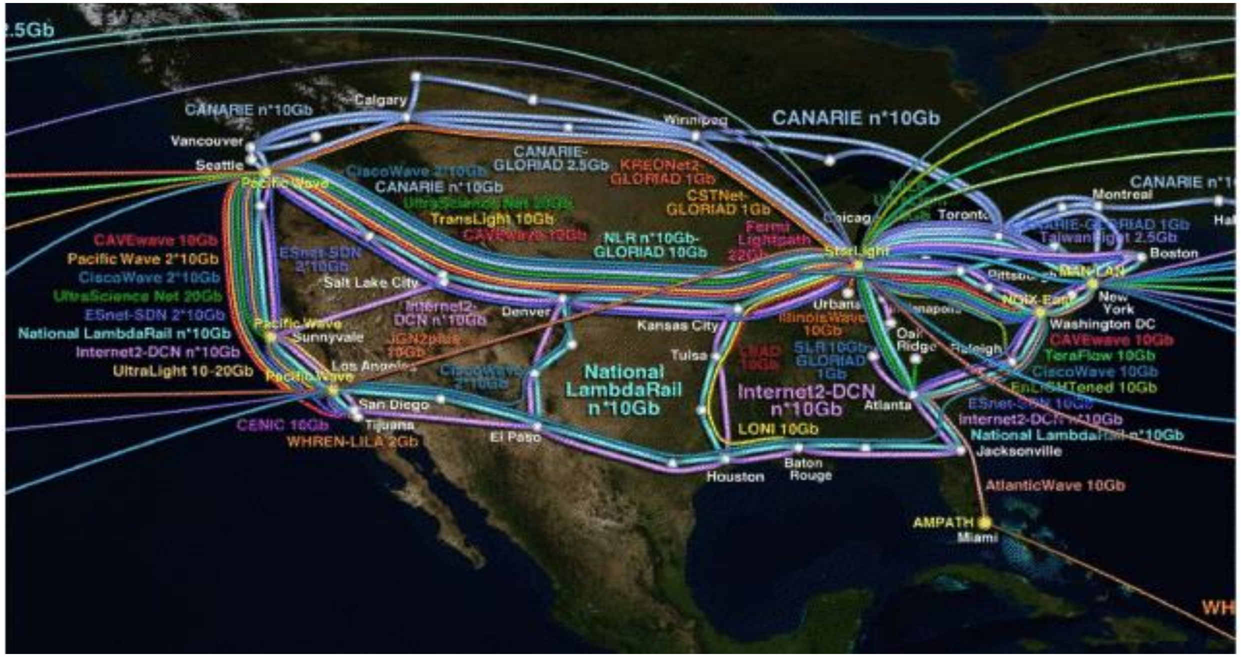
Evolution Of MPST

- Binary Session Types [THK98, HVK98]
- Multiparty Session Types [POPL'08]
- A Theory of Design-by-Contract for Distributed Multiparty Interactions [Concur'11]
- Multiparty Session Types Meet Communicating Automata [ESOP'12, ICALP'13]
- Network Monitoring through Multiparty Session Types [FMOODS'13]

- SPY: Local Verification of Global Protocols [RV'13]
- Distributed Runtime Verification with Session Types and Python [RV'13]

Ocean Observatory Initiative (OOI)

OOI aims: to deploy an infrastructure (global network) to expand the scientists' ability to remotely study the ocean



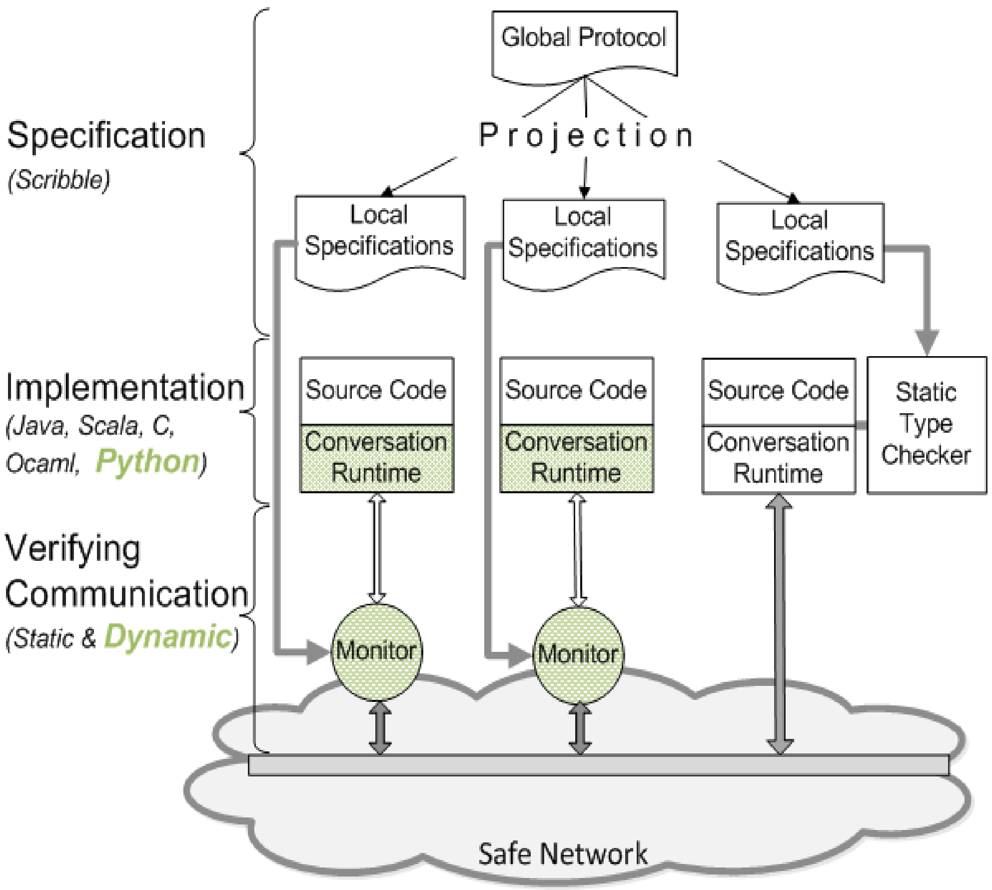
Usage: Integrate real-time data acquisition, processing and data storage for ocean research,…

OOI: verification challenges

- applications written in **different** languages, running on **heterogeneous** hardware in an **asynchronous** network.
- different authentication domains, external **untrusted** applications
- various distributed protocols
- requires correct, safe interactions

Session Types for Runtime Verification

- Methodology
  - Developers design protocols in a dedicated language - Scribble
  - Well-fomedness is checked by Scribble tools
  - Protocols are projected into local types
  - Local types generate monitors



Content

1. Writing correct global protocols with **Scribble Compiler**

2. Verify programs via ***local monitors***

3. Build additional verification modules via ***annotations***

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1. Writing correct global protocols with **Scribble Compiler**

2. Verify programs via ***local monitors***

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Meet Scribble

Scribble

Protocol Language

Follow me on GitHub

"Scribbling is necessary for architects, either physical or computing, since all great ideas of architectural construction come from that unconscious moment, when you do not realise what it is, when there is no concrete shape, only a whisper which is not a whisper, an image which is not an image, somehow it starts to urge you in your mind, in so small a voice but how persistent it is, at that point you start scribbling." Kohei Honda 2007.

What is Scribble?

Scribble is a language to describe application-level protocols among communicating systems. A protocol represents an agreement on how participating systems interact with each other. Without a protocol, it is hard to do a meaningful interaction: participants simply cannot communicate effectively, since they do not know when to expect the other parties to send their data, or whether the other party is ready to receive a datum it is sending. In fact it is not clear what kinds of data is to be used for each interaction. It is too costly to carry out communications based on guess works and with inevitable communication mismatch (synchronisation bugs). Simply, it is not feasible as an engineering practice.

Documents

- Protocol Language Guide

Downloads

- Java Tools

Community

- Discussion Forum
- Java Tools
  - Issues
  - Wiki
- Python Tools
  - Issues
  - Wiki

A Global Protocol

Import type

protocol def

send-receive

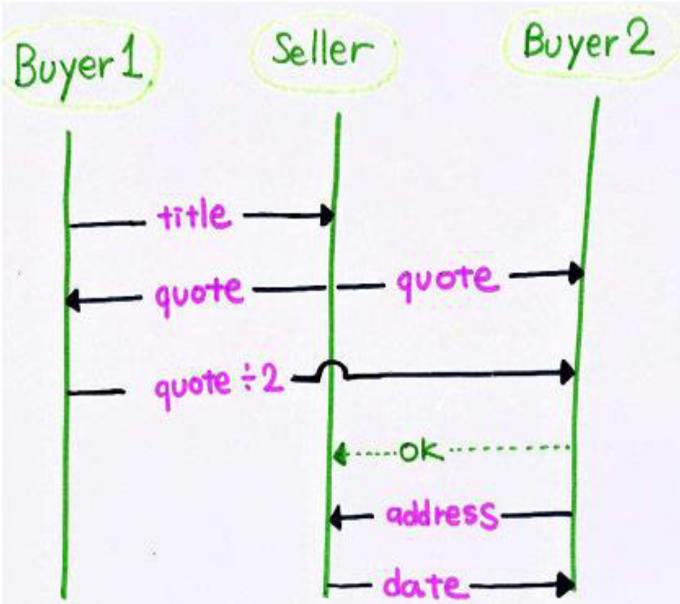
recursion

choice

```
type <python> "StringType" from "Lib/types.py" as str;

global protocol Negotiation(role P, role R, role A) {
    offer(string) from P to R;
    offer(string) from R to A;
    (string) from A to R;
    rec START {
        choice at R {
            accept() from R to P;
            confirm() from P to R;
        } or {
            offer(string) from R to P;
            (conditions:string) from P to R;
            continue START;
        } or {
            reject() from R to P;
            confirm() from R to P;}}}
```

Two Buyer Protocol in Scribble

```
module Bookstore;

type <java> "java.lang.Integer" from "rt.jar" as Integer;
type <java> "java.lang.String" from "rt.jar" as String;

global protocol TwoBuyers(role A, role B, role S) {
    title(String) from A to S;
    quote(Integer) from S to A, B;
    rec LOOP {
        share(Integer) from A to B;
        choice at B {
            accept(address:String) from B to A, S;
            date(String) from S to B;
        } or {
            retry() from B to A, S;
            continue LOOP;
        } or {
            quit() from B to A, S;
}   }   }
```



Buyer: A local projection

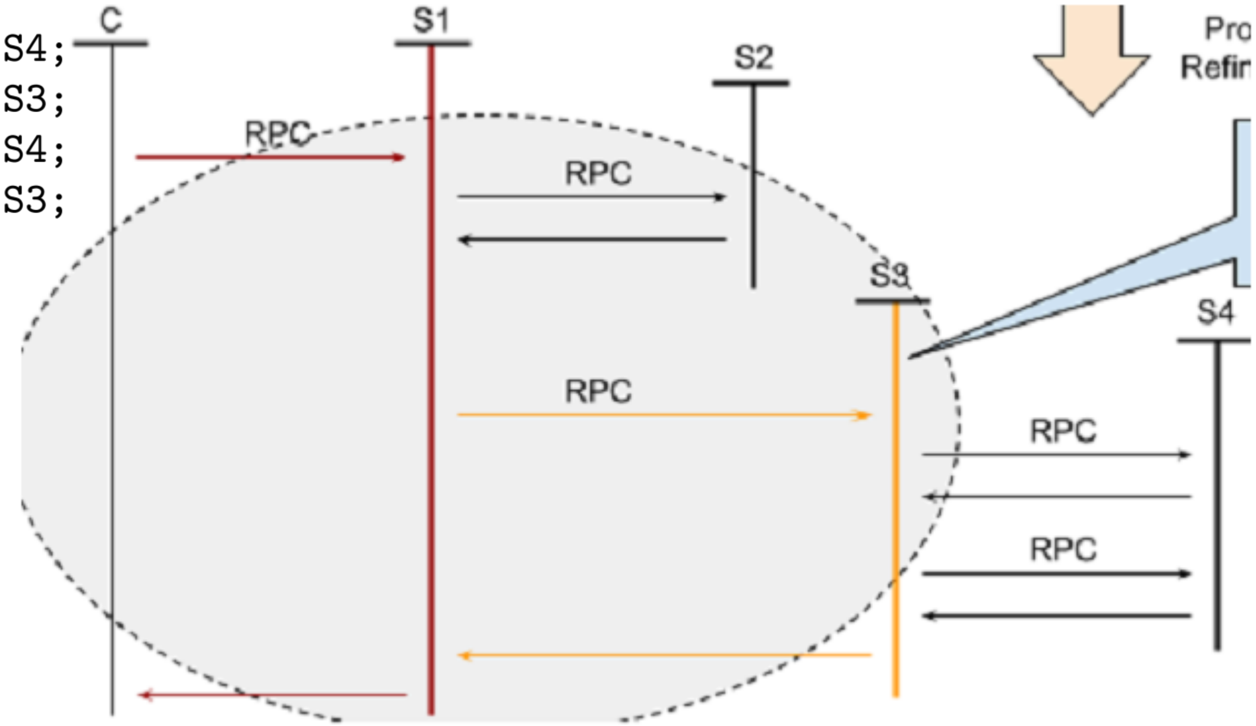
```
module Bookstore_TwoBuyers_A;

type <java> "java.lang.Integer" from "rt.jar" as Integer;
type <java> "java.lang.String" from "rt.jar" as String;

local protocol TwoBuyers_A at A(role A, role B, role S) {
 title(String) to S;
 quote(Integer) from S;
 rec LOOP {
  share(Integer) to B;
  choice at B {
   accept(address:String) from B;
  } or {
   retry() from B;
   continue LOOP;
  } or {
   quit() from B;
} } }
```

Let’s catch some errors: Well-formedness

```
global protocol Protocol1(role A, role B) {
    choice at A {
        m1() from A to B;
    } or {
        m2() from A to B; } }

global protocol Protocol2(role A, role B, role C) {
    choice at A {
        m1() from A to B;
        m1() from B to C; // Additional step
    } or {
        m2() from A to B; } }

global protocol Protocol3(role A, role B, role C) {
    choice at A {
        m1() from A to B;
        m1() from B to C;
    } or {
        m1() from A to B; // Copy-paste error
        m2() from B to C; } }
```

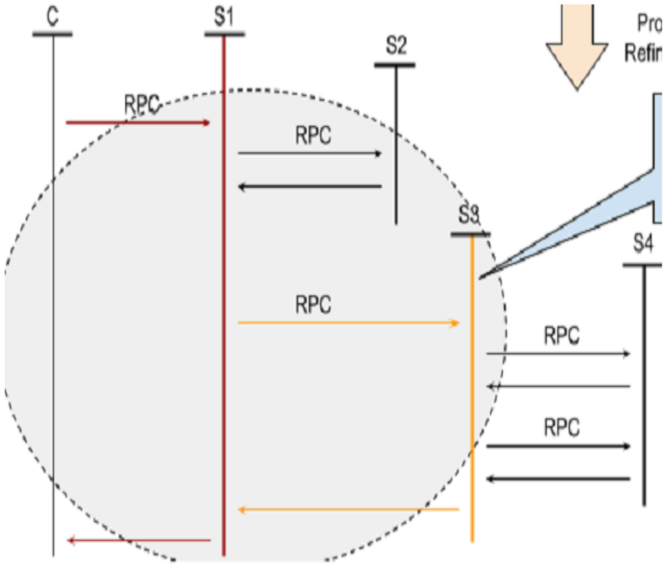
Application-level service call composition

```
// Direct specification
global protocol P3(role C, role S1, role S2, role S3, role S4)
{
    () from C to S1;
        () from S1 to S2;
        () from S2 to S1;
        () from S1 to S3;
            () from S3 to S4;
            () from S4 to S3;
            () from S3 to S4;
            () from S4 to S3;
        () from S3 to S1;
    () from S1 to C;
}
```



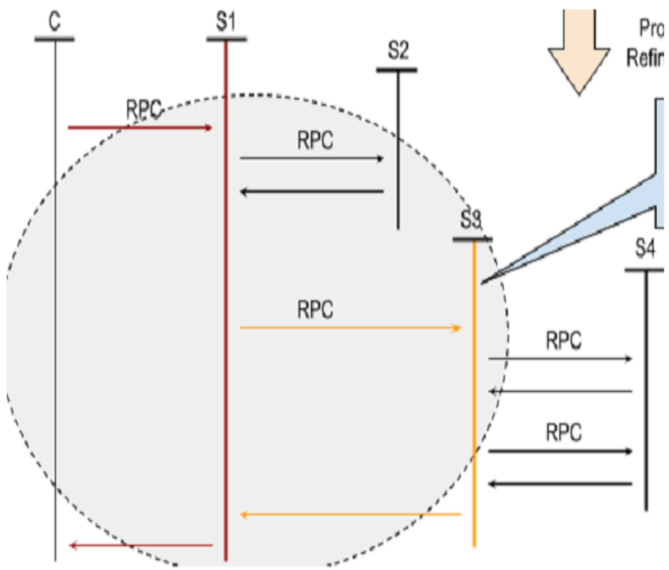
Scoping

```
global protocol ServiceCall(role Client, role Service) {
    () from Client to Server;
    () from Server to Client;
}

// By composing basic ServiceCalls
global protocol P2(role C, role S1, role S2, role S3, role S4)
{
    () from C to S1;
       do ServiceCall(S1 as Client, S2 as Server);
       () from S1 to S3;
          do ServiceCall(S3 as Client, S4 as Server);
          do ServiceCall(S3 as Client, S4 as Serve
       () from S3 to S1;
    () from S1 to C;
}
```



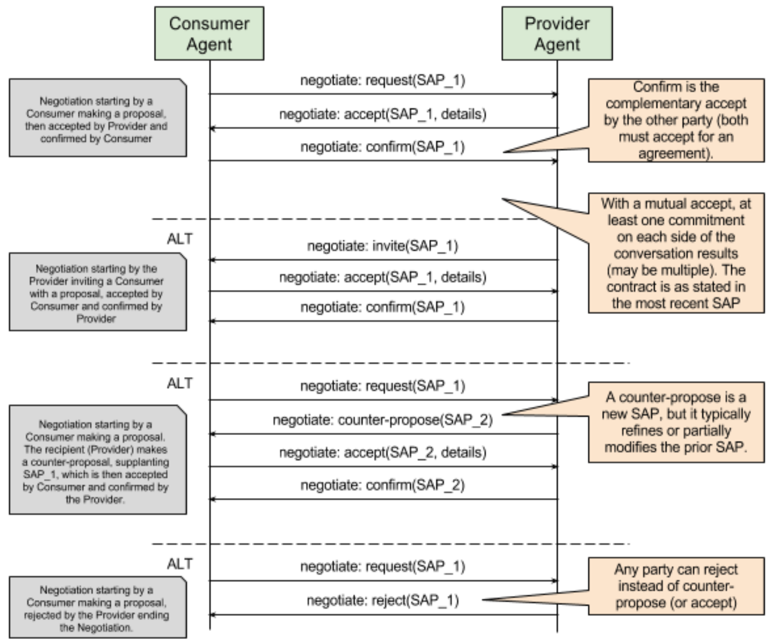
Scoping

```
// "Middleman" pattern
global protocol Middleman(
    role L, role M, role R, role S)
{
 () from L to M;
  do ServiceCall(M as Client, S as Server);
  do ServiceCall(M as Client, S as Server);
 () from M to R;
}
// By composing ServiceCall and Middleman patterns
global protocol P3(role C, role S1, role S2, role S3, role S4)
{
    () from C to S1;
        do ServiceCall(S1 as Client, S2 as Server);
        do Middleman(S1 as L, S3 as M, S4 as R);
    () from S1 to C;
}
```



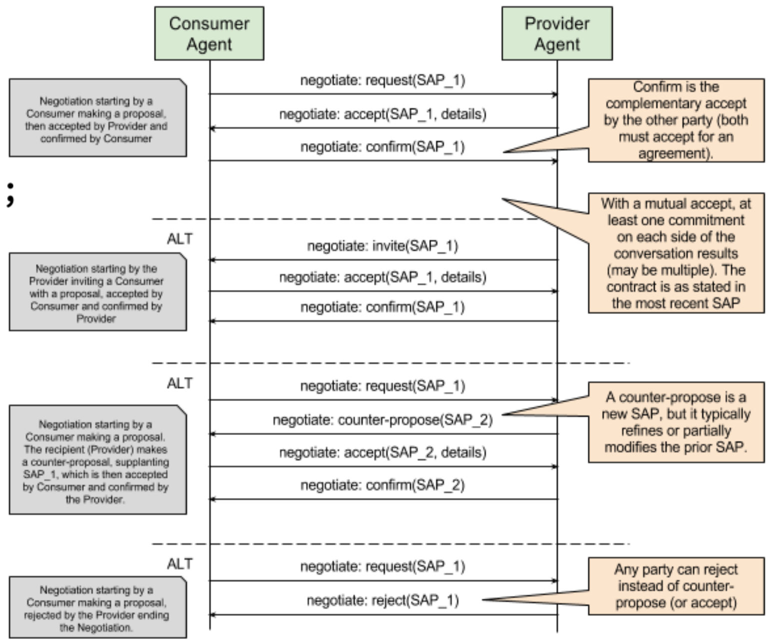
Negotiation protocol in Scribble

```
global protocol Negotiation1(role I, role C) {
 propose(SAP) from I to C;
 @{guard:repeat<10}
 rec START {
  choice at C {
   accept() from C to I;
   confirm() from I to C;
  } or {
   @{deadline: 5s}
   propose(SAP) from C to I;
   choice at I {
    accept() from I to C;
    confirm() from C to I;
   } or {
    reject() from I to C;
   } or {
    propose(SAP) from I to C;
    continue START;
   }
  } or{
   reject() from C to I;
} } }
```



Negotiation protocol in Scribble

```
global protocol Negotiation2(role I, role C) {
    propose(SAP) from I to C;
    do NegotiationAux(I as I, C as C);
}

global protocol NegotiationAux(role I, role C) {
        choice at C {
            accept() from C to I;
            confirm() from I to C;
        } or {
            propose(SAP) from C to I;
            do NegotiationAux(C as I, I as C);
        } or{
            reject() from C to I;
        }
    }
}
```



1. Writing correct global protocols with **Scribble Compiler**

2. Verify programs via ***local monitors***

3. Build additional verification modules via ***annotations***

Local Protocol Conformance

Global Protocol

PROJECTION
(At design time)

LOCAL PROTOCOL FOR P

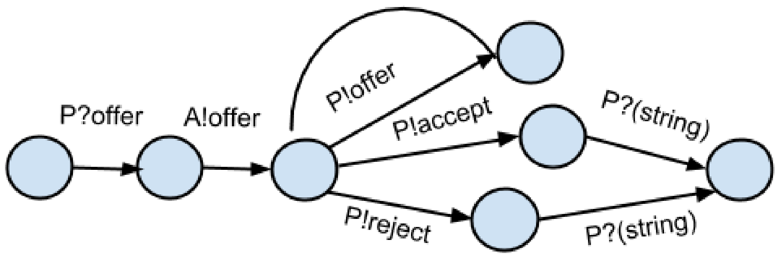
LOCAL PROTOCOL FOR R

```
local protocol Negotiation at R(role P, role A) {
    offer(string) from P;
    offer(string) to A;
    (string) from A;
    rec START {
        choice at R {
            accept() to R;
            (conditions:string) from R;
        } or {
            offer(string) to P;
            continue START;
        } or {
            reject() to P;
           (reason:string) from R;}}}
```

LOCAL PROTOCOL FOR A

FSM GENERATION
(At runtime)

FSM FOR P



FSM FOR A

Verification

PROGRAM FOR P

PROGRAM FOR R

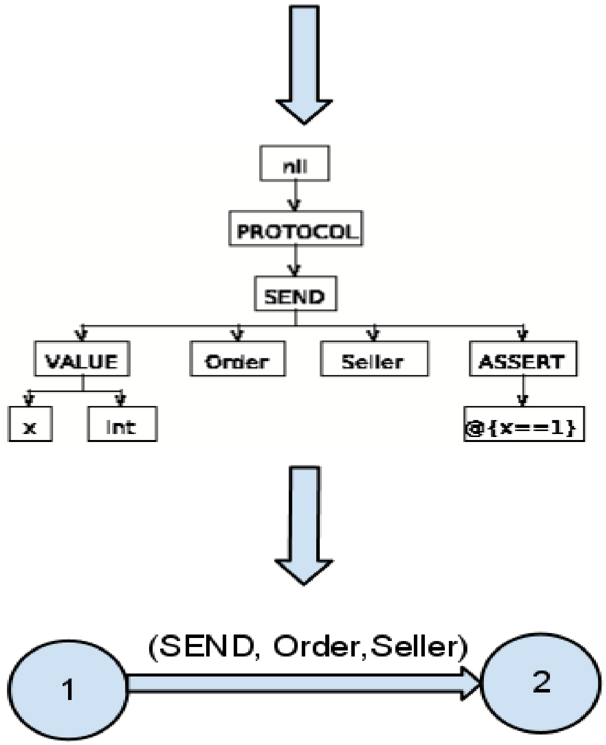
PROGRAM FOR A

FSM Generator

Scribble: Order(x:int) to Seller @{x==1}

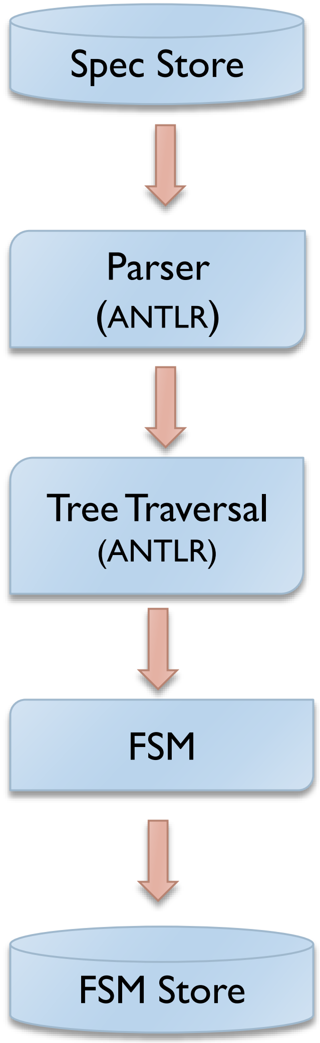
AST:

FSM:

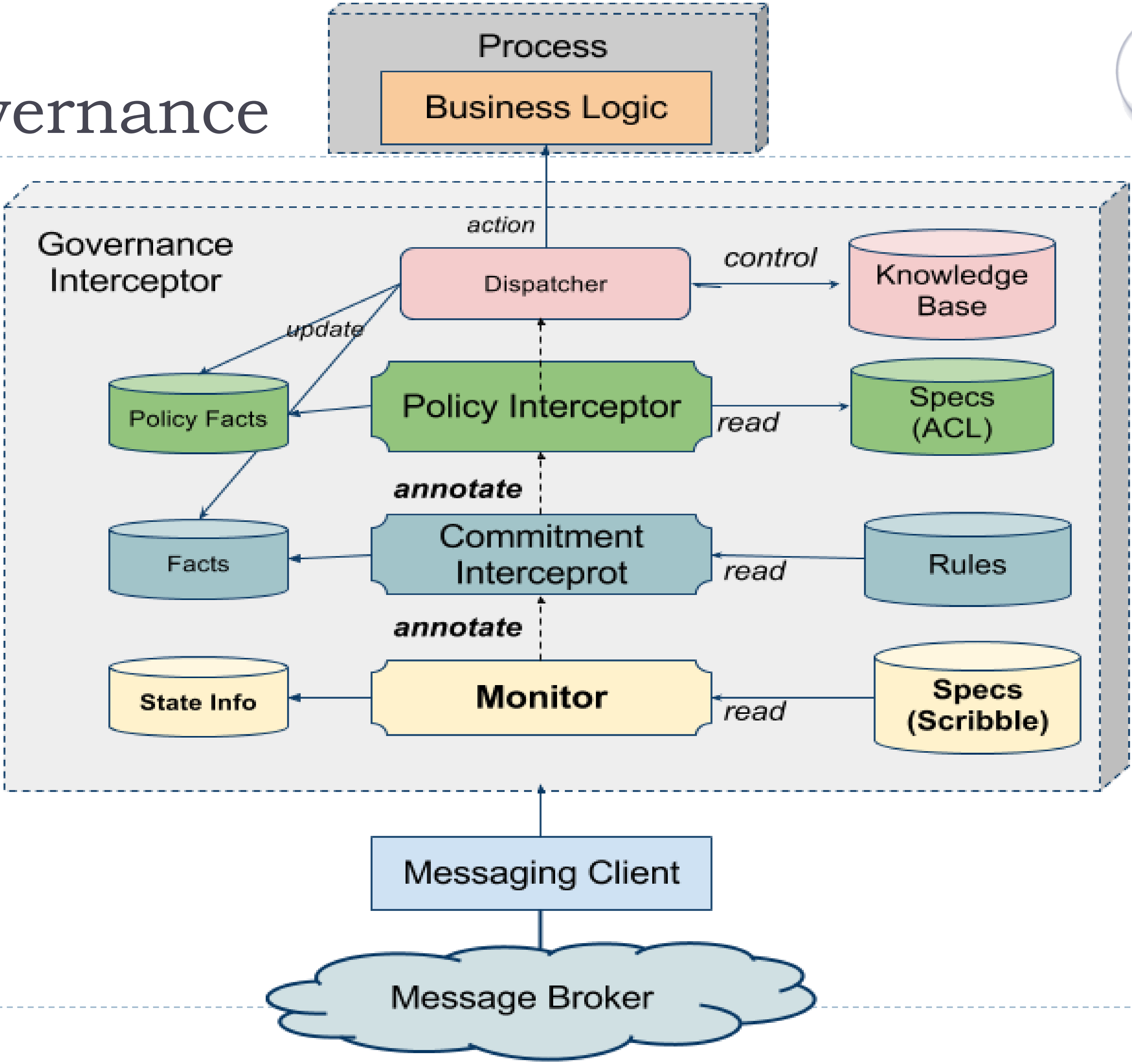


FSM transition_table:

(1, (send, order, seller) ->
(2, assertion_object, {'x':'int'})



Governance



Process
Business Logic
action
Governance Interceptor
Dispatcher
control
Knowledge Base
update
Policy Facts
Policy Interceptor
read
Specs (ACL)
annotate
Facts
Commitment Interceprot
read
Rules
annotate
State Info
Monitor
read
Specs (Scribble)
Messaging Client
Message Broker

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Validation via Annotations

Annotations = @{Logic} Scribble Construct

```
…
{assertion: payment + overdraft>=1000}
offer(payment: int) from C to I;
…
```

```
…
@{deadline: 5s}
offer(payment:  int) from C to I;
…
```

```
…
rec Loop {
@{guard: repeat<10}
offer(payment: int) from C to I;
…
```

- The monitor passes {'type':param, …} to the upper layers
- Upper layers recognize and process the annotation type or discard it
- Stateful assertion

Scribble Community

- Webpage:
  - www.scribble.org
- GitHub:
  - https://github.com/scribble
- Tutorial:
  - www.doc.ic.ac.uk/~rhu/scribble/tutorial.html
- Specification (0.3)
  - www.doc.ic.ac.uk/~rhu/scribble/langref.html

A theory for network monitoring

- Formalise MPST-monitoring and asynchronous networks.
- Introduce monitors as first-class objects in the theory
- Justify monitoring by soundness theorems.
  - Safety
    - monitors enforces specification conformance.
  - Transparency
    - monitors does not affect correct behaviours.
  - Fidelity
    - correspondence to global types is maintained.

Multiparty Sessions for Runtime Monitors

$$A \quad ::= \quad \mathsf{tt} \mid \mathsf{ff} \mid e_1 = e_2 \mid e_1 < e_2 \mid \neg A \mid A_1 \wedge A_2 \mid A_1 \vee A_2$$

$$e \quad ::= \quad v \mid e_1 + e_2 \mid e_1 - e_2 \mid e_1 * e_2 \mid e_1 \;\mathtt{mod}\; e_2 \qquad S ::= \mathsf{bool} \mid \mathsf{int} \mid \mathsf{string}$$

$$G \quad ::= \quad \mathtt{r}_1 \to \mathtt{r}_2 : \{l_i(x_i : S_i)\{A_i\}.G_i\}_{i \in I} \mid G_1 \mid G_2 \mid G_1 ; G_2 \mid \mu \mathsf{t}.G \mid \mathsf{t} \mid \epsilon \mid \mathsf{end}$$

$$T \quad ::= \quad \mathtt{r}!\{l_i(x_i : S_i)\{A_i\}.T_i\}_{i \in I} \mid \mathtt{r}?\{l_i(x_i : S_i)\{A_i\}.T_i\}_{i \in I} \mid T_1 \mid T_2 \mid T_1 ; T_2 \mid \mu \mathsf{t}.T \mid \mathsf{t} \mid \epsilon \mid \mathsf{end}$$

$$P \quad ::= \quad \bar{a}\langle s[\mathtt{r}] : T\rangle \mid a(y[\mathtt{r}] : T).P \mid k[\mathtt{r}_1, \mathtt{r}_2]!l\langle e\rangle \mid k[\mathtt{r}_1, \mathtt{r}_2]?\{l_i(x_i).P_i\}_{i \in I} \mid \mathsf{if}\ e\ \mathsf{then}\ P\ \mathsf{else}\ Q \mid P \mid Q \mid \mathbf{0} \mid \mu X.P \mid X \mid P;Q \mid (\nu a)\,P \mid (\nu s)P$$

$$N \quad ::= \quad [P]_\alpha \mid N_1 | N_2 \mid \mathbf{0} \mid (\nu a)N \mid (\nu s)N \mid \langle r\ ;\ h\rangle$$

$$r \quad ::= \quad a \mapsto \alpha \mid s[\mathtt{r}] \mapsto \alpha \qquad h ::= m \cdot h \mid \emptyset \qquad m ::= \bar{a}\langle s[\mathtt{r}] : T\rangle \mid s\langle \mathtt{r}_1, \mathtt{r}_2, l\langle v\rangle\rangle$$

Formal Semantics

$$
\begin{array}{lcl}
[\overline{a}\langle s[\mathtt{r}] : T\rangle]_\alpha \mid \langle r \,;\, h\rangle & \longrightarrow & [\mathbf{0}]_\alpha \mid \langle r \,;\, h \cdot \overline{a}\langle s[\mathtt{r}] : T\rangle\rangle \\
[a(y[\mathtt{r}] : T).P]_\alpha \mid \langle r \,;\, \overline{a}\langle s[\mathtt{r}] : T\rangle \cdot h\rangle & \longrightarrow & [P[s/y]]_\alpha \mid \langle r \cdot s[\mathtt{r}] \mapsto \alpha \,;\, h\rangle\ ^{\dagger} \\
[s[\mathtt{r}_1, \mathtt{r}_2]!l_j\langle v\rangle]_\alpha \mid \langle r \,;\, h\rangle & \longrightarrow & [\mathbf{0}]_\alpha \mid \langle r \,;\, h \cdot s\langle \mathtt{r}_1, \mathtt{r}_2, l_j\langle v\rangle\rangle\rangle\ ^{\dagger\dagger} \\
[s[\mathtt{r}_1, \mathtt{r}_2]?\{l_i(x_i).P_i\}_i]_\alpha \mid \langle r \,;\, s\langle \mathtt{r}_1, \mathtt{r}_2, l_j\langle v\rangle\rangle \cdot h\rangle & \longrightarrow & [P_j[v/x_j]]_\alpha \mid \langle r \,;\, h\rangle\ ^{\dagger\dagger\dagger}
\end{array}
$$

$$
\dagger : r(a) = \alpha \qquad \dagger\dagger : r(s[\mathtt{r}_2]) \neq \alpha \qquad \dagger\dagger\dagger : r(s[\mathtt{r}_2]) = \alpha
$$

- processes P located at principals α
  - Abstracts local applications
- router r
  - abstracts network routing information updated on-the-fly

Formalism: Monitor

- Specifications

$$\Sigma ::= \emptyset \mid \Sigma, \alpha : \langle \Gamma ; \Delta \rangle,$$

$$\Gamma ::= \emptyset \mid \Gamma, a :?(T[\mathtt{r}]) \mid \Gamma, a :!(T[\mathtt{r}]) \quad \Delta ::= \emptyset \mid \Delta, s[\mathtt{r}] : T,$$

Σ: spec., Δ: session env, Γ: shared env.

- Monitors

$$\mathsf{M} = \alpha : \langle \Gamma ; \Delta \rangle$$

  - Monitors are introduced as component of monitored networks

$$\frac{\mathsf{M} \xrightarrow{s[\mathtt{r}_1,\mathtt{r}_2]!l\langle v\rangle} \mathsf{M}' \quad r(s[\mathtt{r}_2]) \neq \alpha}{[s[\mathtt{r}_1,\mathtt{r}_2]!l\langle v\rangle]_\alpha \mid \mathsf{M} \mid \langle r\ ;\ h\rangle \longrightarrow [\mathbf{0}]_\alpha \mid \mathsf{M}' \mid \langle r\ ;\ h \cdot s\langle \mathtt{r}_1,\mathtt{r}_2, l\langle v\rangle\rangle\rangle}$$

$$\frac{\mathsf{M} \not\xrightarrow{s[\mathtt{r}_1,\mathtt{r}_2]!l\langle v\rangle}}{[s[\mathtt{r}_1,\mathtt{r}_2]!l\langle v\rangle]_\alpha \mid \mathsf{M} \mid \langle r\ ;\ h\rangle \longrightarrow [\mathbf{0}]_\alpha \mid \mathsf{M} \mid \langle r\ ;\ h\rangle}$$

Satisfaction

The satisfaction relation $\models N : \Sigma$ relates networks and specification:

- if Σ expects an input, N should be able to process it.
- if N performs an output, Σ should be expecting it.
- still holds after reduction (coinductive definition).

Satisfaction equivalence

If $N_1 \cong N_2$ and $\models N_1 : \Sigma$ then $\models N_2 : \Sigma$.

Results (Safety)

Local Safety

$\models [P]_\alpha \mid \mathsf{M} : \alpha : \langle \Gamma; \Delta \rangle$ with $\mathsf{M} = \alpha : \langle \Gamma; \Delta \rangle$.

- A monitored process satisfies its specification.

Global Safety

If N is fully monitored w.r.t. Σ, then $\models \mathsf{N} : \Sigma$.

- monitored networks behave as expected.

Results (Transparency)

Local Transparency

If $\models [P]_\alpha \ : \ \alpha : \langle \Gamma; \Delta \rangle$, then $[P]_\alpha \approx ([P]_\alpha \mid \mathsf{M})$ with $\mathsf{M} = \alpha : \langle \Gamma; \Delta \rangle$.

- unmonitored correct processes are undistinguishable from their monitored counterparts.
- allows one to mix monitored and typechecked processes.

Global Transparency

Assume N and N have the same global transport $\langle r \ ; \ h \rangle$.
Assume:

1. N is fully monitored w.r.t. Σ and
2. $N = M \mid \langle r \ ; \ h \rangle$ is unmonitored but $\models M \ : \ \Sigma$.

We have $\mathsf{N} \cong N$.

- monitors does not alterate behaviors of correct networks.
- monitor actions are not observable on correct components.

Results (Fidelity)

- a configuration is consistent: when it corresponds to a well-formed array of global types $(G_1, \ldots, G_n)$ through projection.
- conformance is satisfaction + receivability (queue can be emptied).

Session Fidelity

Assume:

1. configuration $\Sigma; \langle r \; ; \; h \rangle$ is consistent,
2. network $N \equiv M | \langle r \; ; \; h \rangle$ conforms to configuration $\Sigma; \langle r \; ; \; h \rangle$.

For any ℓ, whenever we have $N \xrightarrow{\ell}_{\mathrm{g}} N'$ s.t. $\Sigma; \langle r \; ; \; h \rangle \xrightarrow{\ell}_{\mathrm{g}} \Sigma'; \langle r' \; ; \; h' \rangle$, it holds that $\Sigma'; \langle r' \; ; \; h' \rangle$ is consistent and N' conforms to $\Sigma'; \langle r' \; ; \; h' \rangle$.

- consistence is preserved by reduction,
- at any time, the network correspond to a well-formed specification.

Summary

- Having a context allows to control the communication
- Having granularity allows to specify constraints on the interactions
- Early error detection is much cheaper
- High-level policies on top of protocol verification
- Good abstraction means easy programming – you program with send and receive (no threads, sockets, channels)

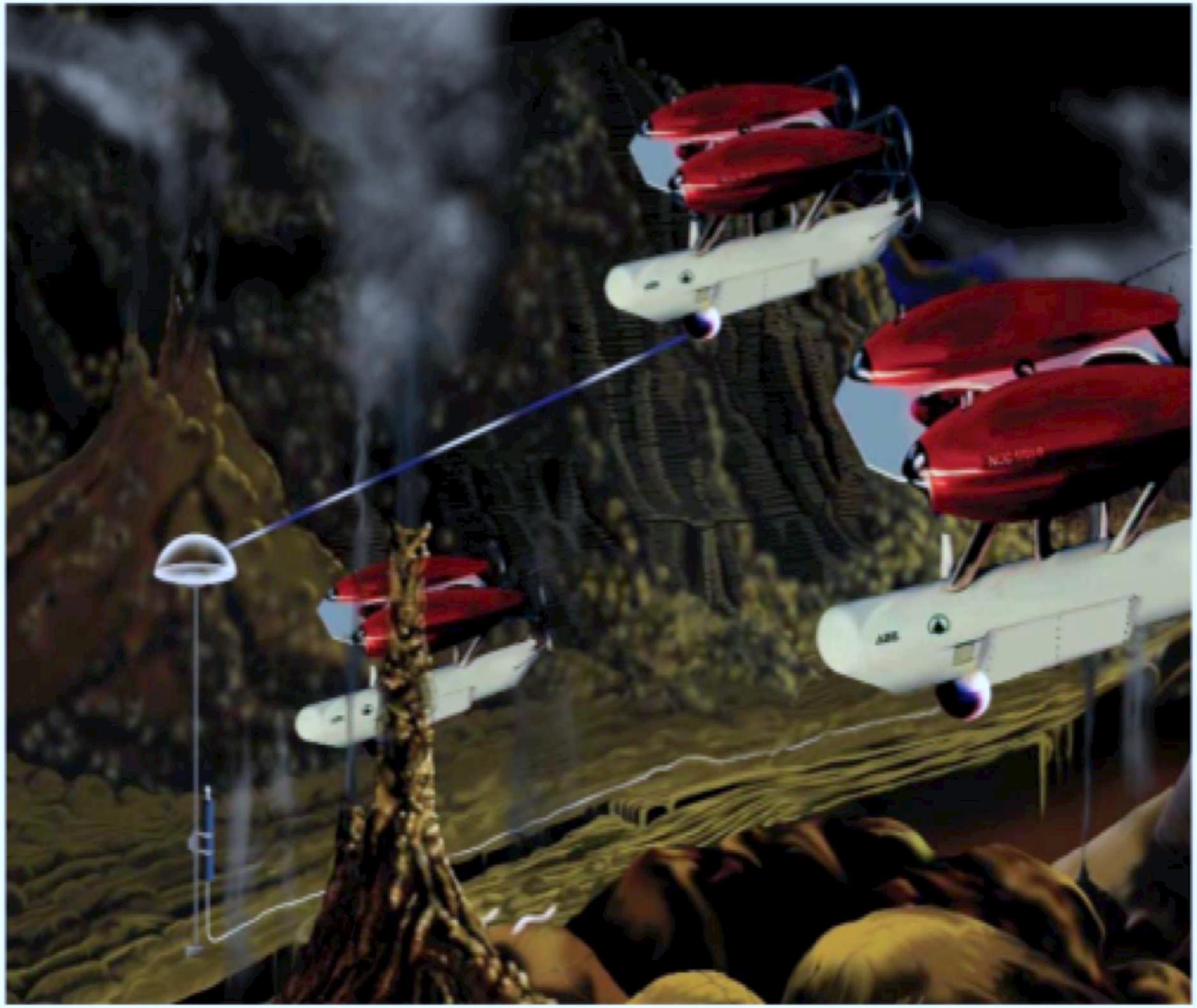


Figure 5: A coordinated set of autonomous underwater vehicles

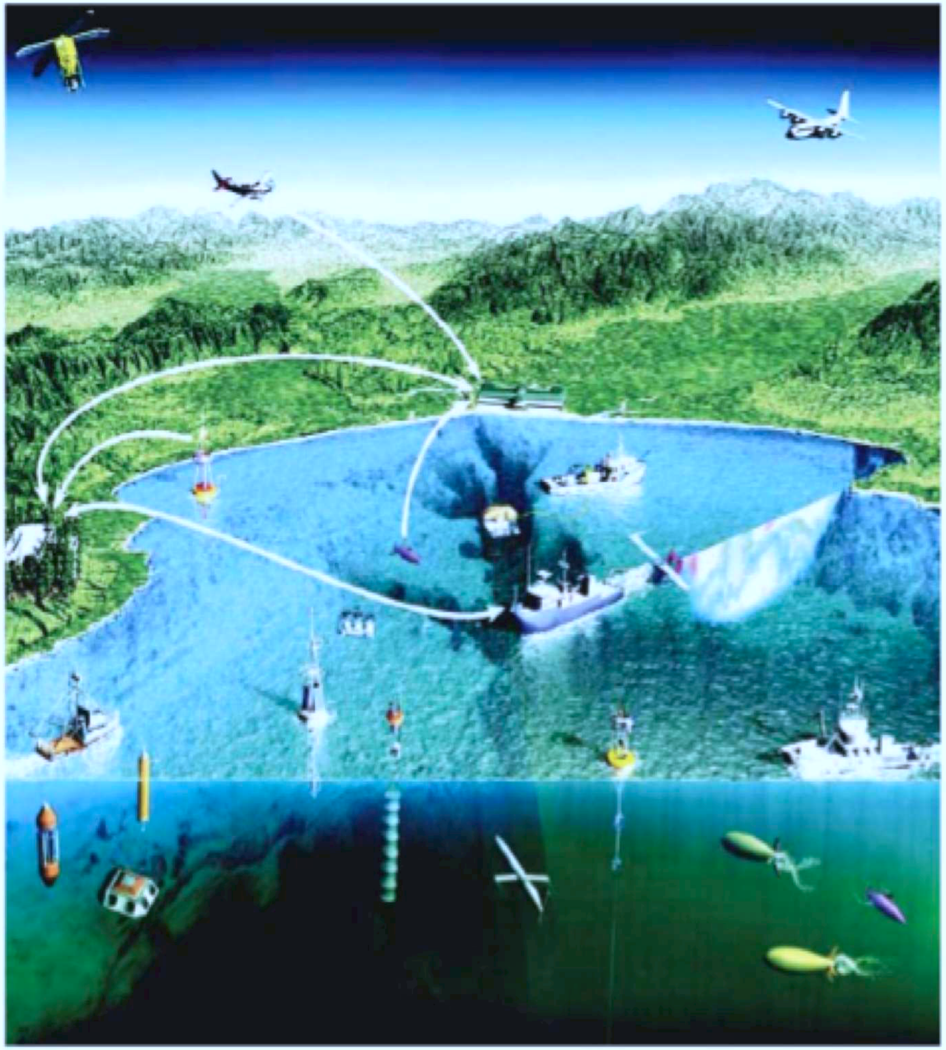
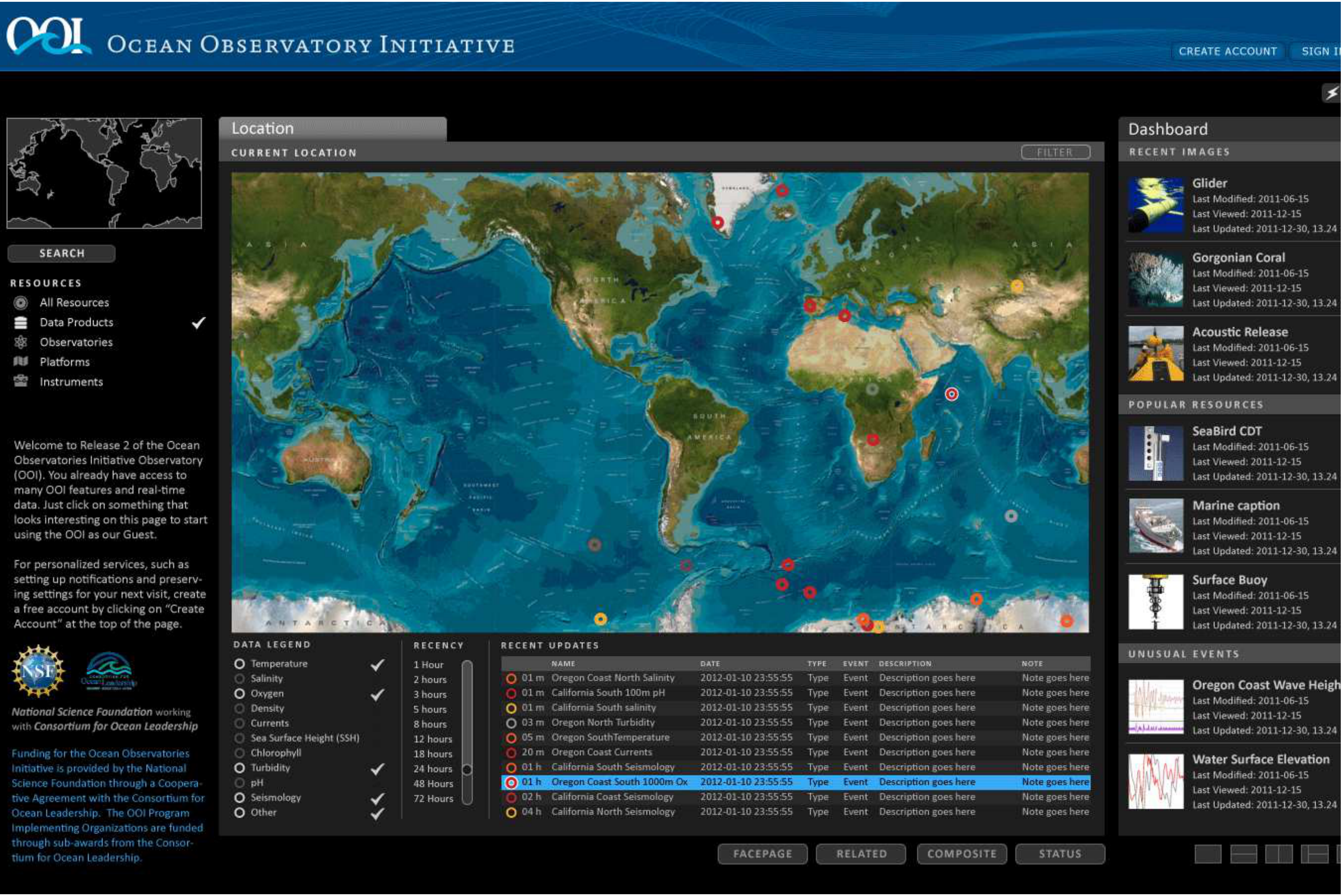


Figure 3: Observatory comprised of ships, aircraft and autonomous vehicles linked to assimilation modeling capabilities on shore


OOI
Ocean Observatory Initiative
CREATE ACCOUNT
SIGN I
Location
CURRENT LOCATION
FILTER
SEARCH
RESOURCES
All Resources
Data Products
Observatories
Platforms
Instruments
Welcome to Release 2 of the Ocean Observatories Initiative Observatory (OOI). You already have access to many OOI features and real-time data. Just click on something that looks interesting on this page to start using the OOI as our Guest.
For personalized services, such as setting up notifications and preserving settings for your next visit, create a free account by clicking on "Create Account" at the top of the page.
National Science Foundation working with Consortium for Ocean Leadership
Funding for the Ocean Observatories Initiative is provided by the National Science Foundation through a Cooperative Agreement with the Consortium for Ocean Leadership. The OOI Program Implementing Organizations are funded through sub-awards from the Consortium for Ocean Leadership.
ASIA
NORTH AMERICA
SOUTH AMERICA
EUROPE
ANTARCTICA
DATA LEGEND
Temperature
Salinity
Oxygen
Density
Currents
Sea Surface Height (SSH)
Chlorophyll
Turbidity
pH
Seismology
Other
RECENCY
1 Hour
2 hours
3 hours
5 hours
8 hours
12 hours
18 hours
24 hours
48 Hours
72 Hours
RECENT UPDATES
NAME DATE TYPE EVENT DESCRIPTION NOTE
01 m Oregon Coast North Salinity 2012-01-10 23:55:55 Type Event Description goes here Note goes here
01 m California South 100m pH 2012-01-10 23:55:55 Type Event Description goes here Note goes here
01 m California South salinity 2012-01-10 23:55:55 Type Event Description goes here Note goes here
03 m Oregon North Turbidity 2012-01-10 23:55:55 Type Event Description goes here Note goes here
05 m Oregon SouthTemperature 2012-01-10 23:55:55 Type Event Description goes here Note goes here
20 m Oregon Coast Currents 2012-01-10 23:55:55 Type Event Description goes here Note goes here
01 h California South Seismology 2012-01-10 23:55:55 Type Event Description goes here Note goes here
01 h Oregon Coast South 1000m Ox 2012-01-10 23:55:55 Type Event Description goes here Note goes here
02 h California Coast Seismology 2012-01-10 23:55:55 Type Event Description goes here Note goes here
04 h California North Seismology 2012-01-10 23:55:55 Type Event Description goes here Note goes here
FACEPAGE
RELATED
COMPOSITE
STATUS
Dashboard
RECENT IMAGES
Glider
Last Modified: 2011-06-15
Last Viewed: 2011-12-15
Last Updated: 2011-12-30, 13.24
Gorgonian Coral
Last Modified: 2011-06-15
Last Viewed: 2011-12-15
Last Updated: 2011-12-30, 13.24
Acoustic Release
Last Modified: 2011-06-15
Last Viewed: 2011-12-15
Last Updated: 2011-12-30, 13.24
POPULAR RESOURCES
SeaBird CDT
Last Modified: 2011-06-15
Last Viewed: 2011-12-15
Last Updated: 2011-12-30, 13.24
Marine caption
Last Modified: 2011-06-15
Last Viewed: 2011-12-15
Last Updated: 2011-12-30, 13.24
Surface Buoy
Last Modified: 2011-06-15
Last Viewed: 2011-12-15
Last Updated: 2011-12-30, 13.24
UNUSUAL EVENTS
Oregon Coast Wave Heigh
Last Modified: 2011-06-15
Last Viewed: 2011-12-15
Last Updated: 2011-12-30, 13.24
Water Surface Elevation
Last Modified: 2011-06-15
Last Viewed: 2011-12-15
Last Updated: 2011-12-30, 13.24

Multiparty Session Type Theory

- Multiparty Asynchronous Session Types [POPL'08]
- Progress
  - Global Progress in Dynamically Interleaved Multiparty Sessions [CONCUR'08], [Math. Struct. Comp. Sci.]
  - Inference of Progress Typing [Coordination'13]
- Asynchronous Optimisations and Resource Analysis
  - Global Principal Typing in Partially Commutative Asynchronous Sessions [ESOP'09]
  - Higher-Order Pi-Calculus [TLCA'07,TLCA'09]
  - Buffered Communication Analysis in Distributed Multiparty Sessions [CONCUR'10]

- Logics
  - Design-by-Contract for Distributed Multiparty Interactions [CONCUR'10]
  - Specifying Stateful Asynchronous Properties for Distributed Programs [CONCUR'12]
  - Multiparty, Multi-session Logic [TGC'12]
- Extensions of Multiparty Session Types
  - Multiparty Symmetric Sum Types [Express'10]
  - Parameterised Multiparty Session Types [FoSSaCs'10, LMCS]
  - Global Escape in Multiparty Sessions [FSTTCS'10] [Math. Struct. Comp. Sci.]
  - Dynamic Multirole Session Types [POPL'11]
  - Nested Multiparty Sessions [CONCUR'12]

- Dynamic Monitoring
  - Asynchronous Distributed Monitoring for Multiparty Session Enforcement [TGC'11]
  - Monitoring Networks through Multiparty Sessions [FORTE'13]
- Automata Theories
  - Multiparty Session Automata [ESOP'12]
  - Synthesis in Communicating Automata [ICALP'13]
- Typed Behavioural Theories
  - On Asynchronous Eventful Session Semantics [FORTE'11] [Math. Struct. Comp. Sci.]
  - Governed Session Semantics [CONCUR'13]
- Choreography Languages
  - Compositional Choreographies [CONCUR'13]

Language and Implementations

- Carrying out large-scale experiences with OOI, VMWare, Red Hat, Congnizant, UNIFI, TrustCare
  - JBoss SCRIBBLE [ICDCIT'10, COB'12] and SAVARA projects
- High-performance computing

  Session Java [ECOOP'08,ECOOP'10,Coordination'11]

  $\Longrightarrow$ Multiparty Session C and MPI [TOOLS'12][Hearts'12][EuroMPI'12]
- Multiparty session languages Ocaml, Java, C, Python, Scala, Jolie
  - Trustworthy Pervasive Healthcare Services via Multiparty Session Types [FHIES'12]
  - SPY: Local Verification of Global Protocols [RV'13]
  - Practical interruptible conversations: Distributed dynamic verification with session types and Python [RV'13]

Session Type Projects

- SADEA EPSRC *Exploiting Parallelism through Type Transformations for Hybrid Manycore Systems*, with Vanderbauwhede, Scholz, Gay and Luk
- Programme Grant EPSRC *From Data Types to Session Types: A Basis for Concurrency and Distribution*, with Wadler and Gay
- EPSRC *Conversation-Based Governance for Distributed Systems by Multiparty Session Types*
- FETOpen UpScale with de Boer, Clark, Drossopoulou, Johnsen and Wrigstad
- VMware Dynamic Assurance based on Multiparty Session Types
- Cognizant EPSRC Knowledge Transfer Secondments

Session Type Reading List

- [ESOP'98] Honda, Vasconcelos and Kubo, Language Primitives and Type Disciplines for Structured Communication-based Programming,
- [SecRet'06] Yoshida and Vasconcelos, Language Primitives and Type Disciplines for Structured Communication-based Programming Revisited, ENTCS.
- [ECOOP'08] Hu, Yoshida and Honda, Session-Based Distributed Programming in Java
- [POPL'08] Carbone, Yoshida and Honda, Multiparty Asynchronous Session Types
- [WS-FM'09] Dezani-Ciancaglini and de'Liguoro, Sessions and Session Types
- [TOOLS'12] Ng, Yoshida and Honda, Multiparty Session C
- [CONCUR'10] Caires and Pfenning, Session Types as Intuitionistic Linear Propositions; [ICFP'12] Walker, as Classical Linear Propositions.
- [OOI] Video by John Orcutt, Professor of Geophysics, UCSD, Ocean Observing: Oceanography in the 21st Century

A rare cluster of qualities

From the team of OOI CI:

Kohei has lead us deep into the nature of communication and processing. His esthetics, precision and enthusiasm for our mutual pursuit of formal Session (Conversation) Types and specifically for our OOI collaboration to realize this vision in very concrete terms were, as penned by Henry James, lessons in seeing the nuances of both beauty and craft, through a rare cluster of qualities - curiosity, patience and perception; all at the perfect pitch of passion and expression.