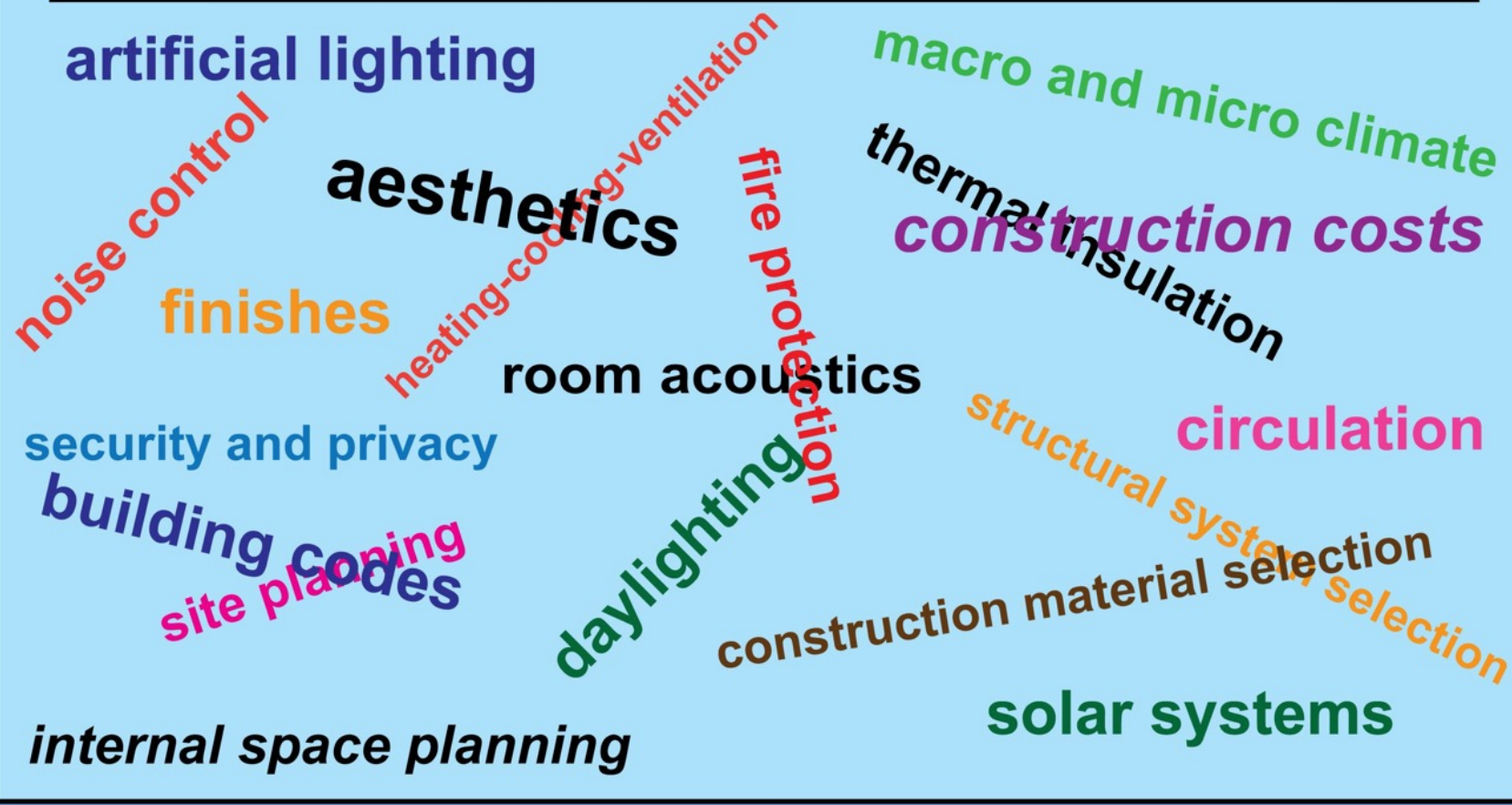
Current Architectural Design

Building Design Issues

The design of even a relatively simple low-rise building can be a *complex* task involving many issues.



21st Century Architectural Design

Ecological Considerations

While *design* is the shaping of matter, energy and process to meet an objective, *ecological design* is the effective utilization of resources in *synchrony with natural processes*.

Guiding principles include:

- Built environment should *not disrupt the ecosystem*.
- Construction materials should *not be toxic* and should be *recyclable*.
- Freshwater should be *drawn sparingly* and *recycled* through multiple uses.
- Selection of *energy sources* and *efficient use of energy* are critical criteria.

21st Centruy Architectural Design

Additional Building Design Issues

Architectural design in the 20th century was already a ***complex*** undertaking due to the relationships and design issues ranging from space planning to structural and environmental system selection.

Additional *sustainability* issues in the 21st century:

- Material selection based on embodied energy, non-toxicity, and recycling.
- Minimization of fresh water usage to 10% of current use.
- Waste treatment and recycling, including the building itself at end of lifespan.
- Energy-neutral or net-energy producing buildings.

21st Century Architectural Design

Sustainability Principles

Anything we build today should be *sustainable* throughout its lifespan and protect the natural environment for future generations.

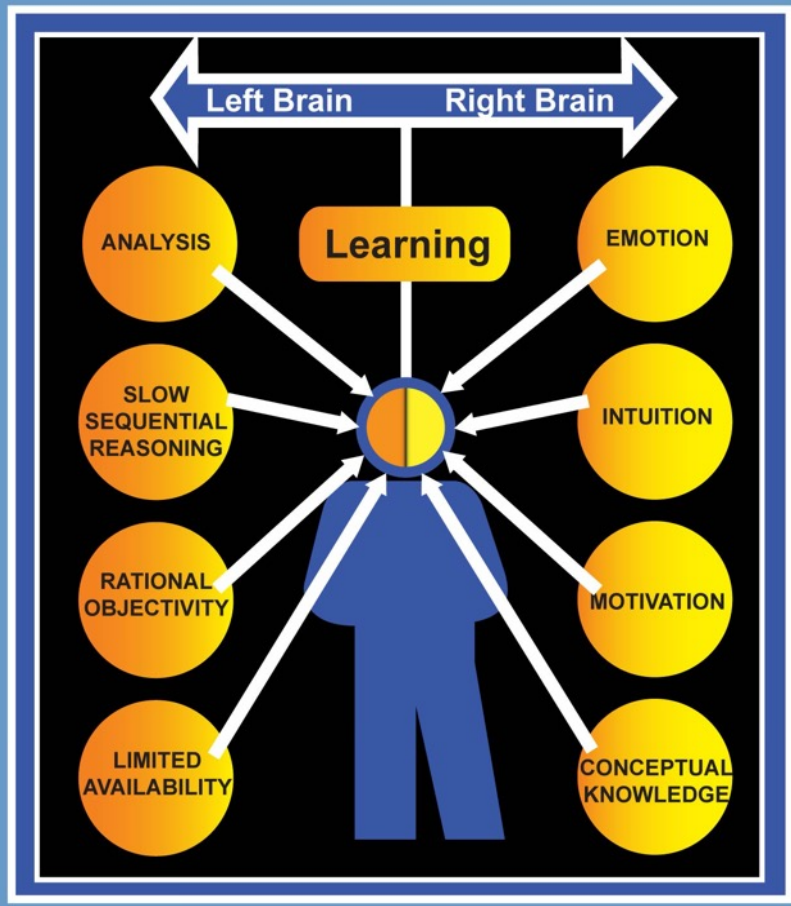
To meet *sustainability* criteria, buildings need to:

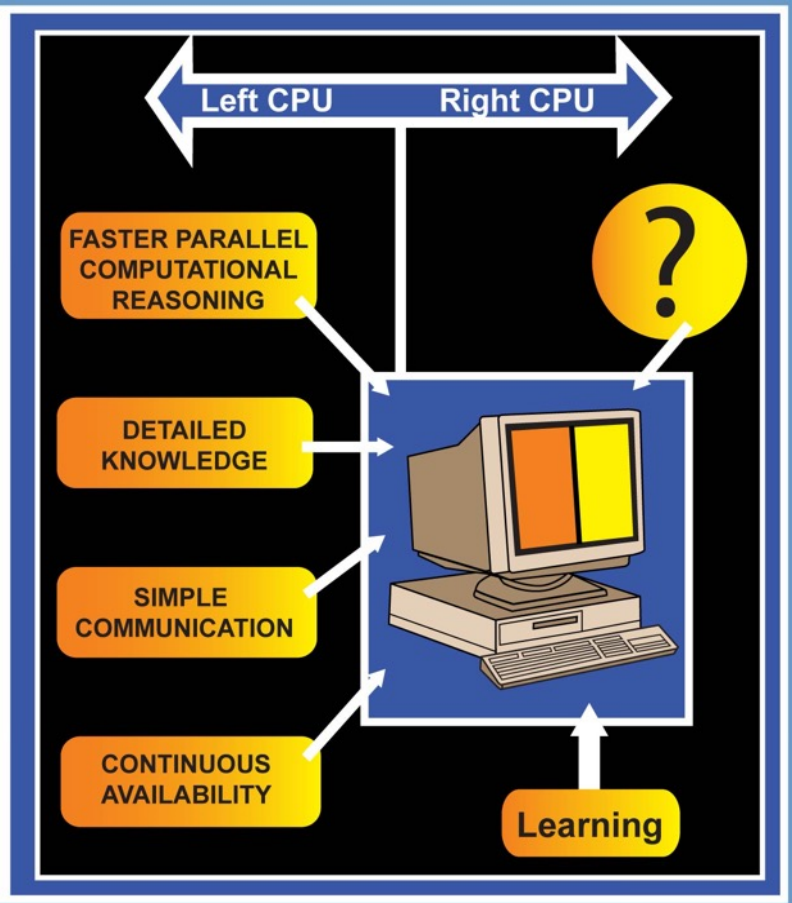
- **Be constructed of materials that are *reusable*.**
- **Be constructed of *low embodied energy* materials.**
- **Be as close to *energy self-sufficiency* as possible.**
- **Incorporate a *waste management* system.**
- **Capture and *recycle graywater*.**
- **Be able to be *deconstructed* and *recycled*.**

Design Environment Requirements

1 *Emphasis on Partnership*

The design environment should assist and extend the capabiities of the human designer, not only *reactively* through monitoring, but also *proactively* through anticipation of user needs.

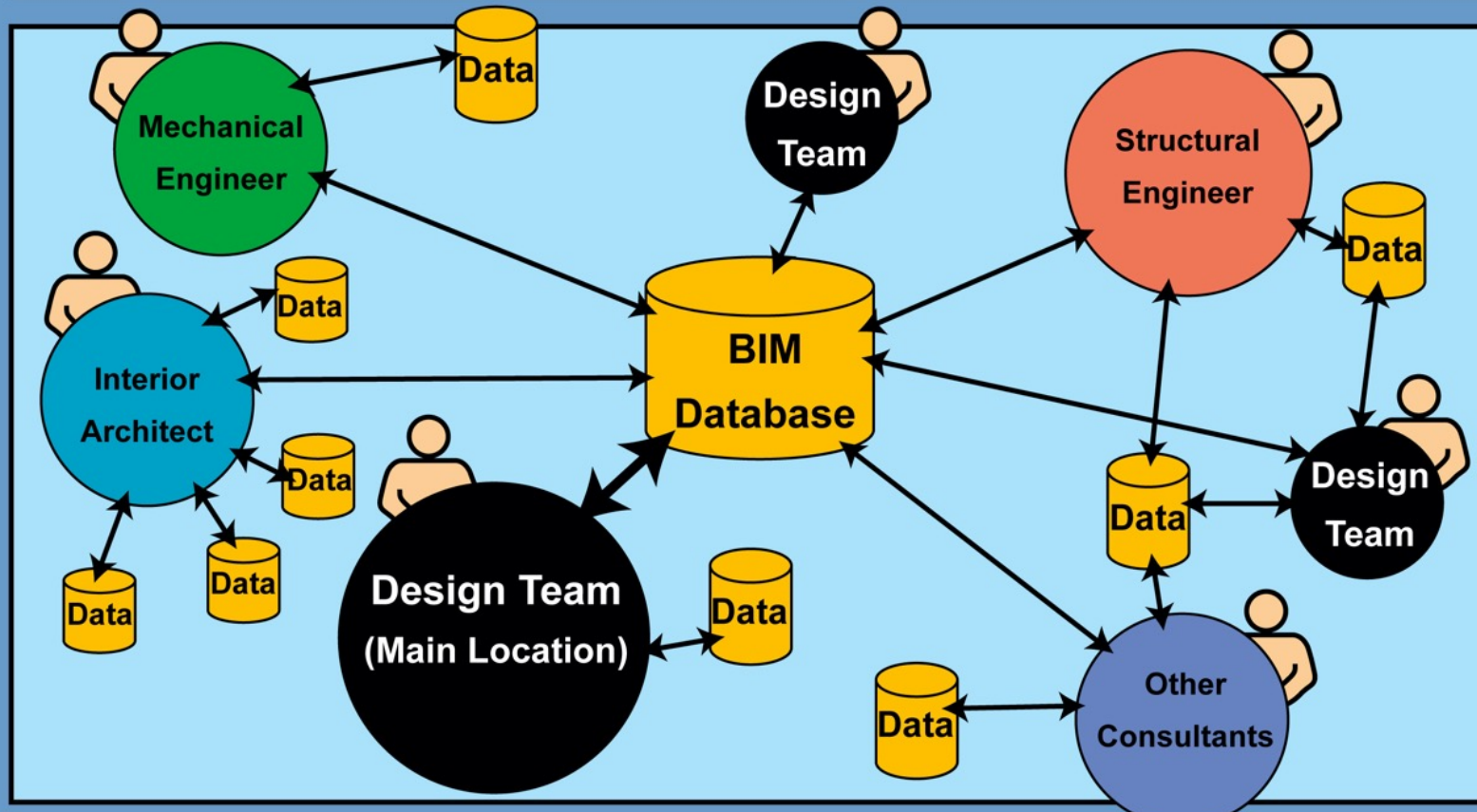




Design Environment Requirements

2 *Collaborative and Distributed*

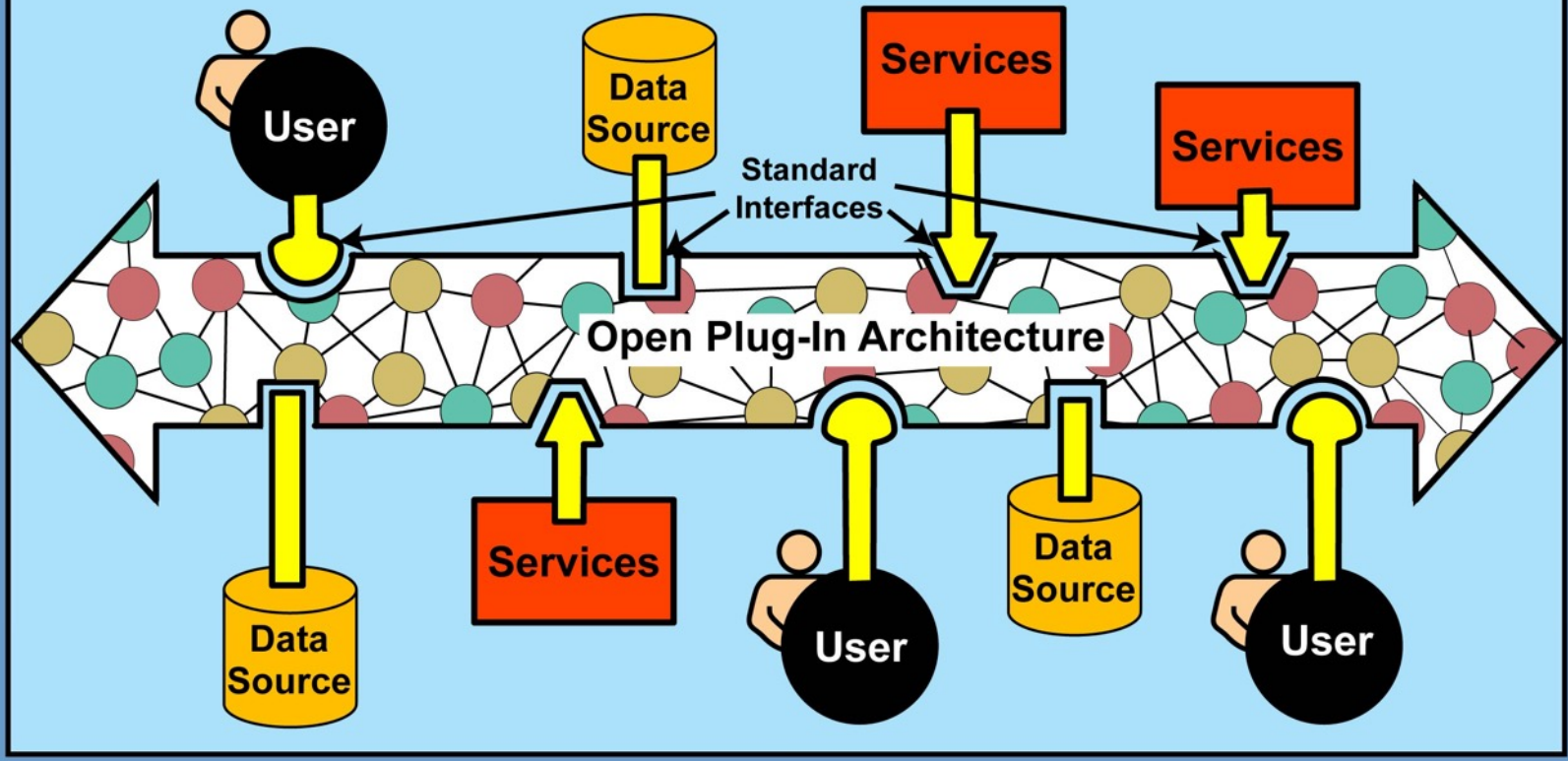
The design activity often involves *many parties* that collaborate from *widely distributed* locations and require access to *dispersed data sources*.



Design Environment Requirements

3 *Open Architecture*

Uncertainty **is a major characteristic of design. This calls for an** ***open system architecture*** **with** ***standard interface protocols*** **that can more easily accommodate changes in data sources and capabilities.**



Design Environment Requirements

4 *Tools not Solutions*

The *indeterminate* nature of design does not allow either the specific circumstances of a future design problem or the precise terms of the solution to be predicted in advance.

Building designers need tools that are:

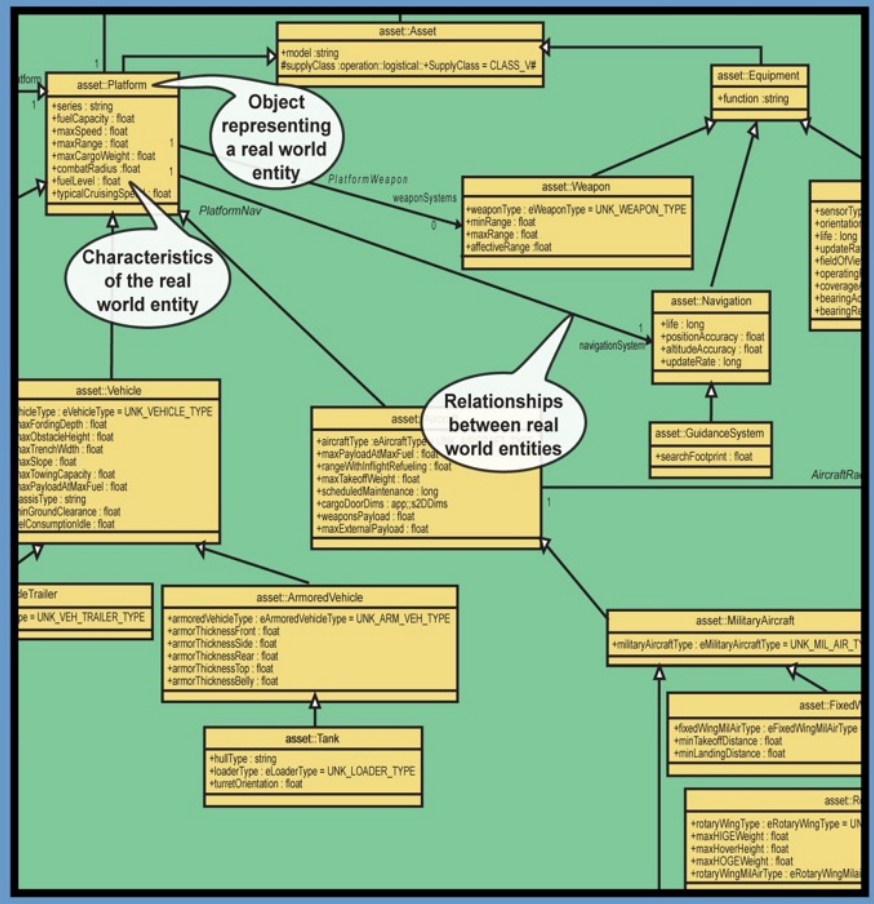
- ***Adaptive***
- ***Self-activating***
- ***Intelligent***
- ***Collaborative***
- ***Semi-autonomous***
- ***User-friendly***

artificial lighting
noise control
aesthetics
finishes
security and privacy
building codes
site planning
internal space planning
macro and micro climate
construction costs
insulation
circulation
material selection
solar systems
room acoustics

Design Environment Requirements

5 *Expressive Internal Representation*

A high level representation of the *context of the design problem* is the most important prerequisite for an intelligent collaborative design environment.

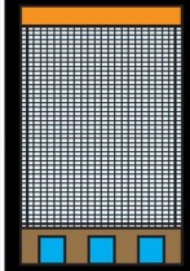


Design Environment Requirements

6 *Embedded Knowledge*

Designers usually rely on *experience* in the form of rules, case studies, standard practices, and typical solutions encapsulated in *prototypes*, as a principal source of information.

Vertical Prototype knowledge bases contain typical information for a complete problem situation or complete artifact such as a building, or aircraft.



BUILDING TYPE

TYPICAL USER NEEDS
- PROFILES
- FUNCTIONS
- ACTIVITIES

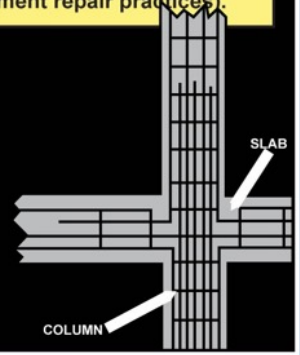
TYPICAL OWNER NEEDS
- EXPECTATIONS
- CONSTRAINTS

TYPICAL DESIGN CRITERIA
- STRUCTURE
- CONSTRUCTION
- SERVICES

Exemplar Prototype knowledge bases describe a specific solution such as an outstanding building or a method (e.g., welding technique) that can be applied across several disciplines.

Horizontal Prototype knowledge bases contain typical solutions for sub-problems that may apply to more than one discipline (e.g., equipment repair practices).

STANDARD PRACTICES
- SUB-PROBLEM SOLUTION
- VALIDATED
- REPLICABLE



Domain Prototype knowledge bases contain information and guidelines for developing solutions within contributing narrow domains.

DOMAIN SPECIFIC
- SPECIALIZED
- DISCIPLINE-BASED

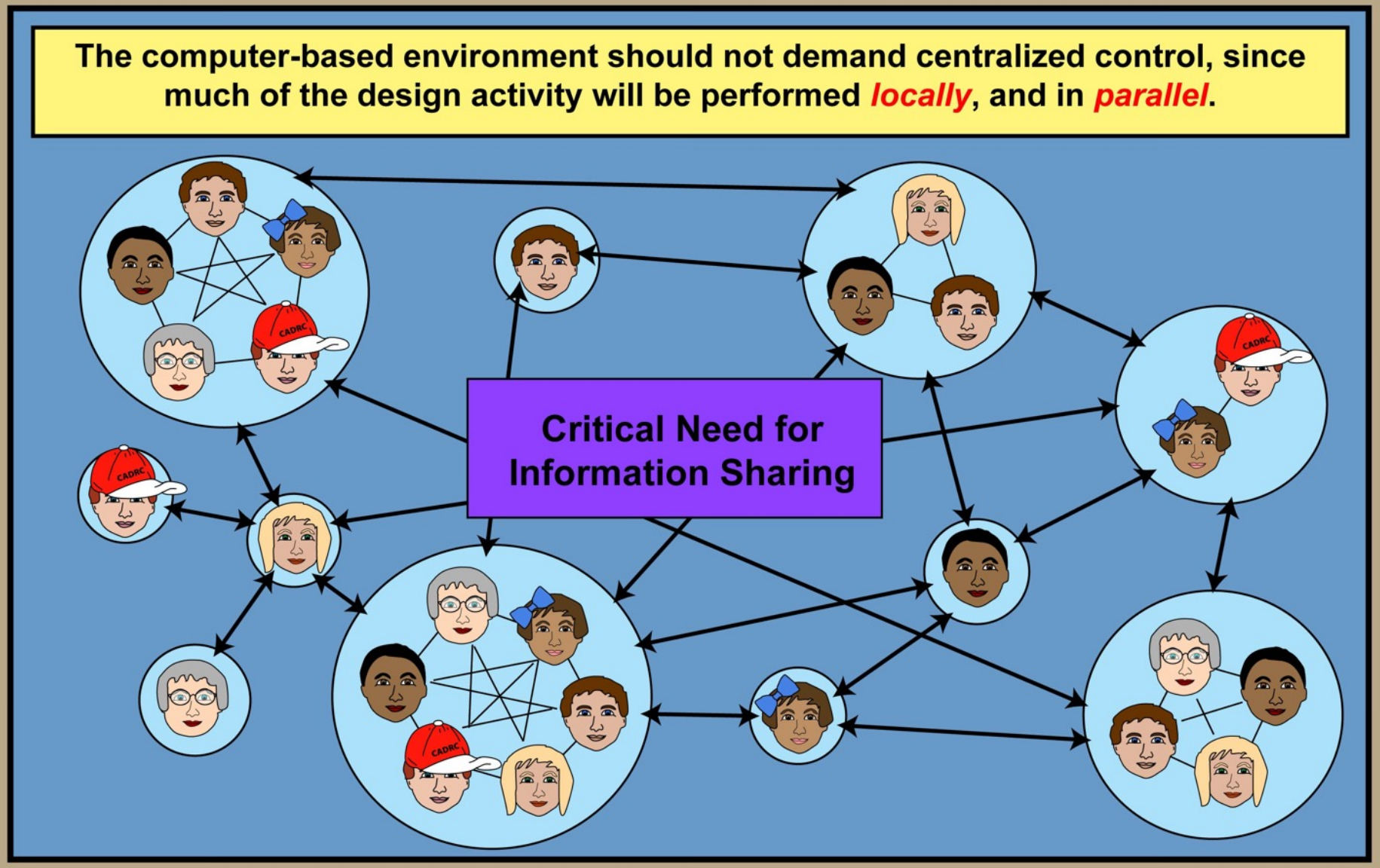
Experiential Prototype knowledge bases contain information about actual solutions, or events, or memorable experiences that can be reapplied.

EXPERIENTIAL ARCHETYPE

Design Environment Requirements

7 *Decentralized Decision Making*

The computer-based environment should not demand centralized control, since much of the design activity will be performed *locally*, and in *parallel*.



Design Environment Requirements

8 *Conflict Identification*

As the degree of complexity of a design problem increases, the emphasis should be on *conflict identification* rather than automatic conflict resolution.

Computer Role

- Recognize the existence of a conflict.
- Determine the kind of conflict.
- Trace the relationships that produced the conflict.

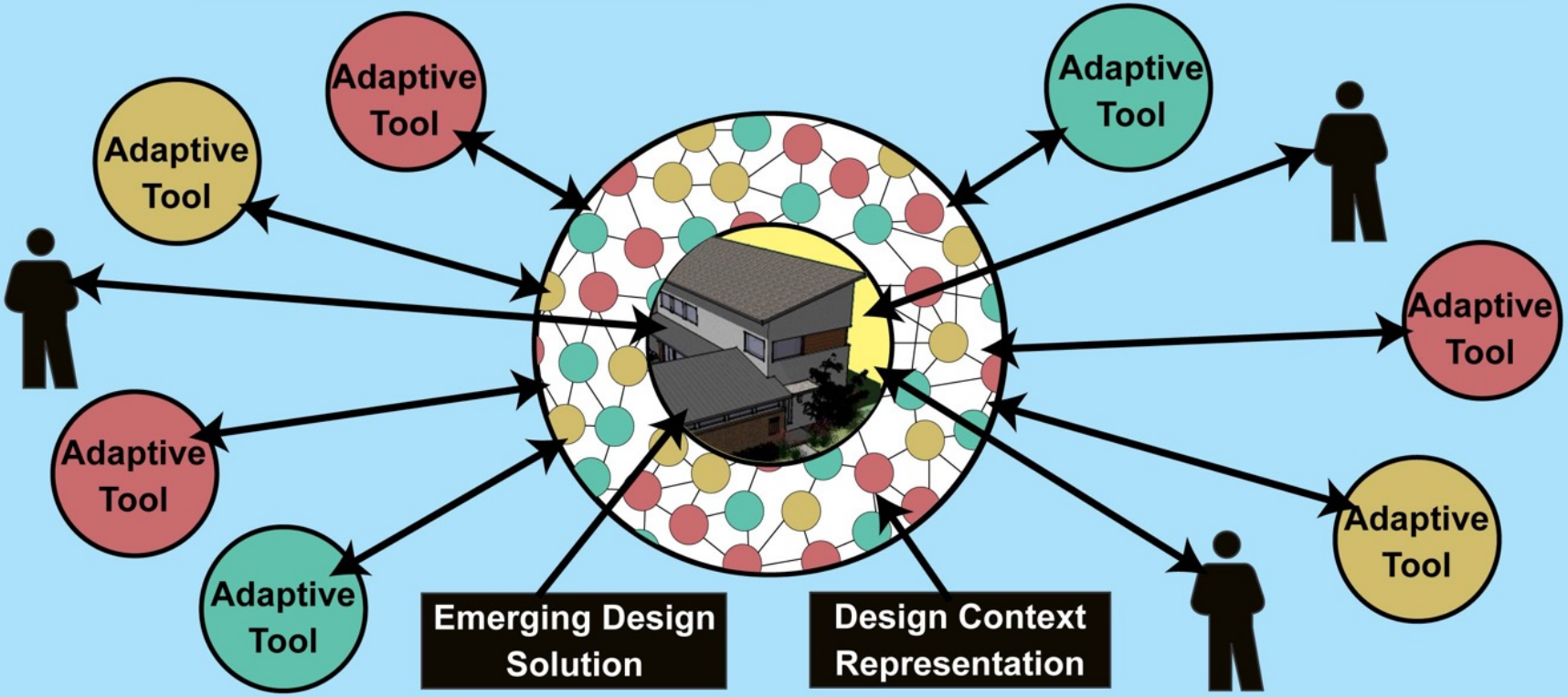
Human Role

- Recognize the cause of the conflict.
- Explore the implications of the conflict.
- Resolve the conflict.

Design Environment Requirements

9 *Adaptive Intelligent Tools*

The designer needs adaptive tools because both the design criteria and even the solution objectives are subject to *change* during the design activity.



Communication **among adaptive tools allows the relationships among design issues to be maintained dynamically and in parallel.**

Design Environment Requirements

10 *Human-Computer Interface*

The designer should be able to *interact* with the design environment and its various capabilities in *multiple ways*.

- Utilizing 2-D and animated 3-D *visualizations*.
- Requesting *explanations* of agent evaluations and proposals.
- Receiving meaningful *agent warnings* and *alerts*.
- Pursuing *semantic* search operations.
- Invoking structural and environmental *simulations*.

... within the meaningful *context* of the semantic internal representation of the design state and domain.

Design Environment Requirements

Explanation Facilities

The ability of the design environment to be able to explain its responses *increases* in proportion to the level of embedded intelligence.

What Questions: **What is the heat loss of this window in the east wall of the conference room?**

How Questions: **How will the structural frame react to a 90 mph wind force?**

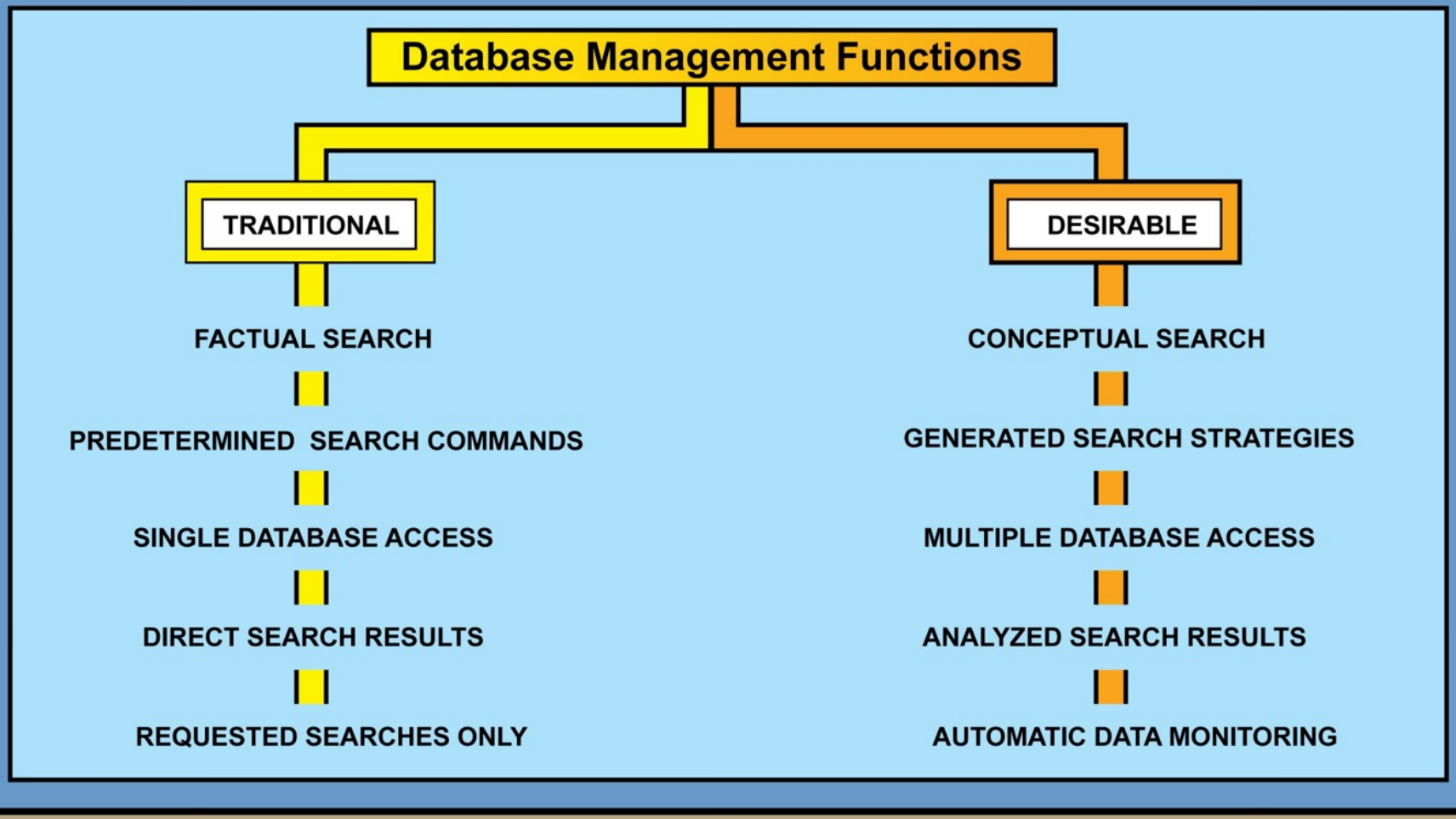
Why Questions: **Why is the building requiring cooling during the early afternoon of a typical winter day?**

Why questions **are most complicated because they typically involve the inference sequences of several agents.**

Design Environment Requirements

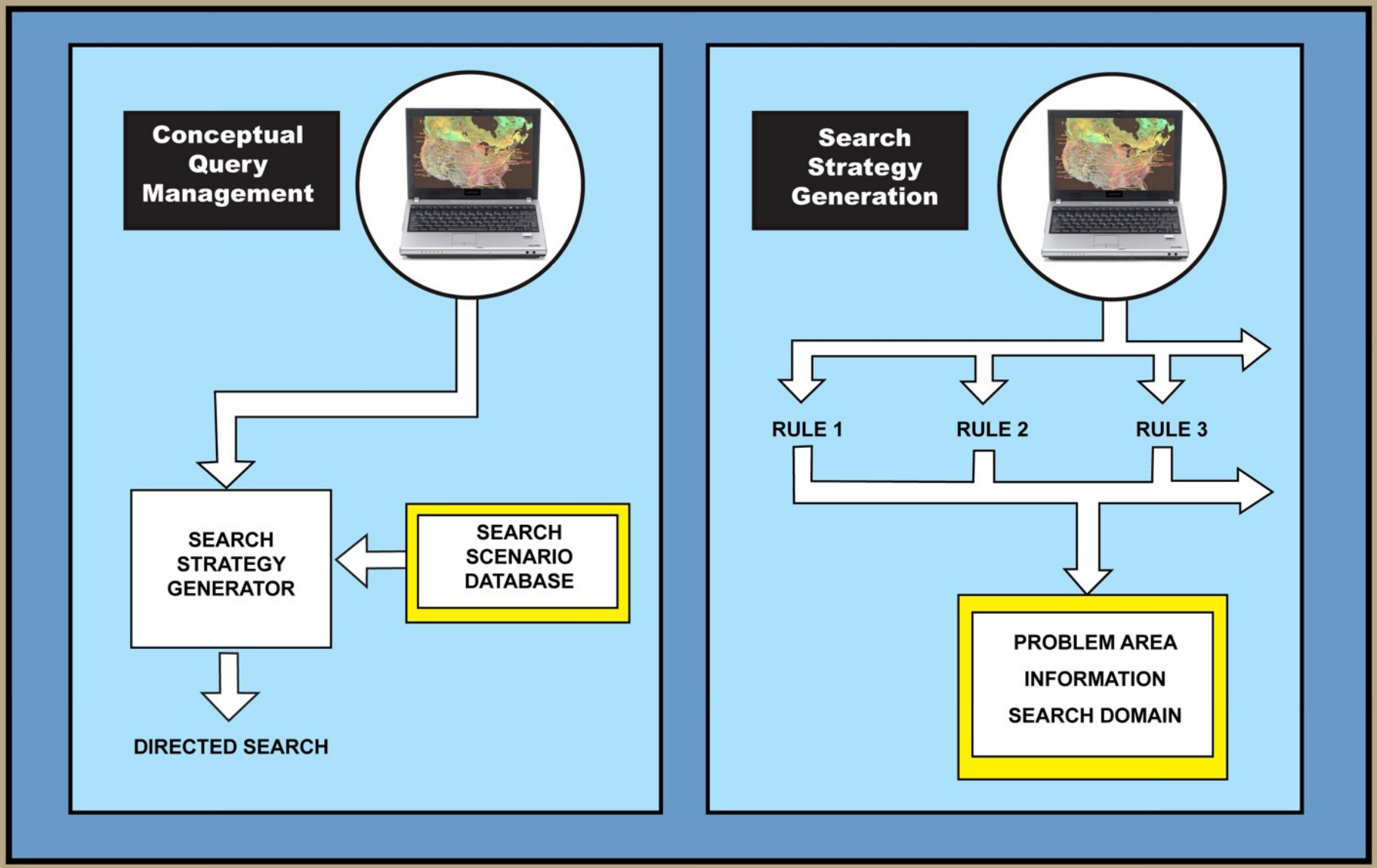
Semantic Search Facilities

An intelligent design environment should be able to respond to *inexact queries*, because the designer may not know exactly what information is required.



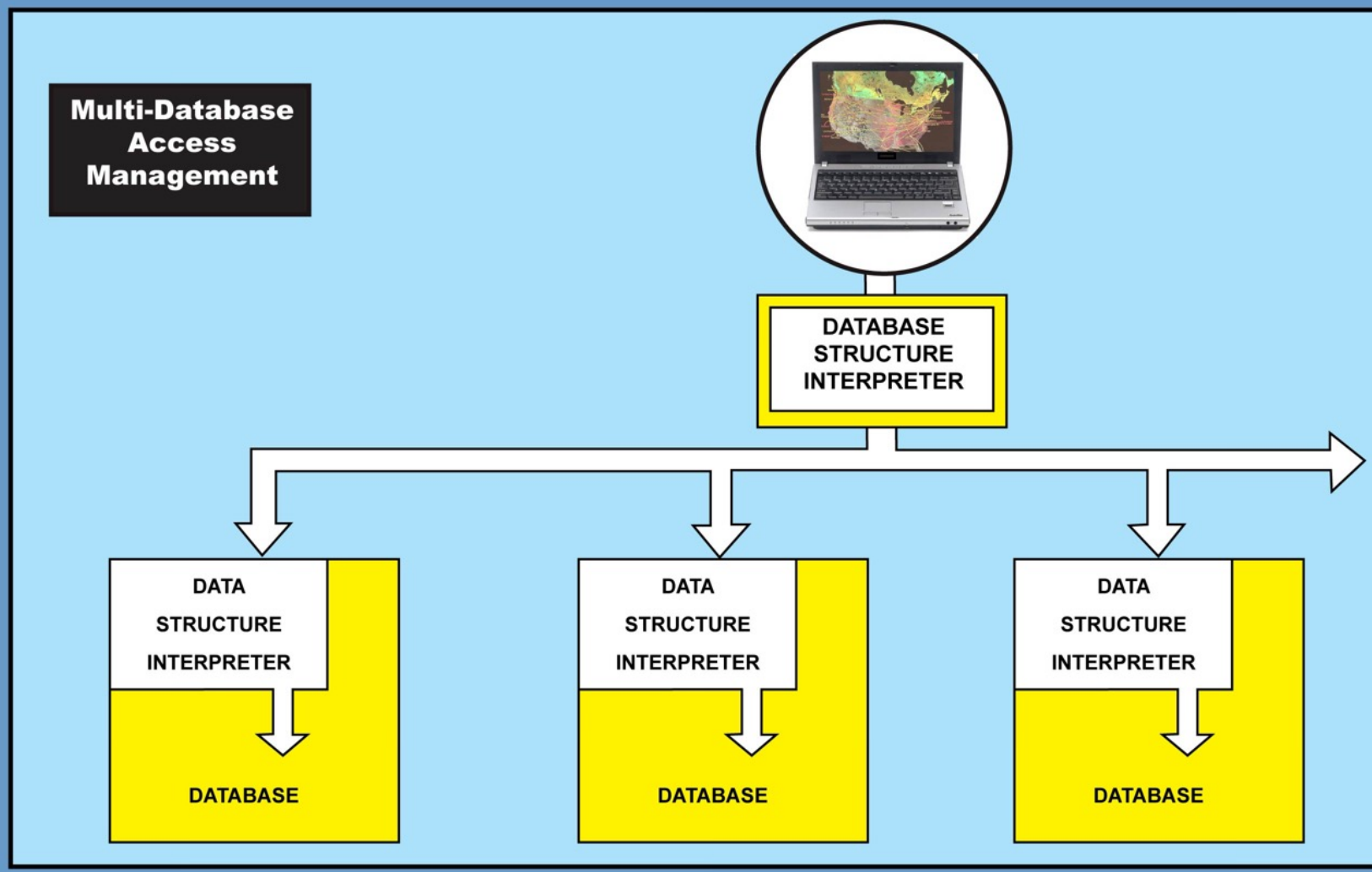
Design Environment Requirements

Semantic Query Formulation



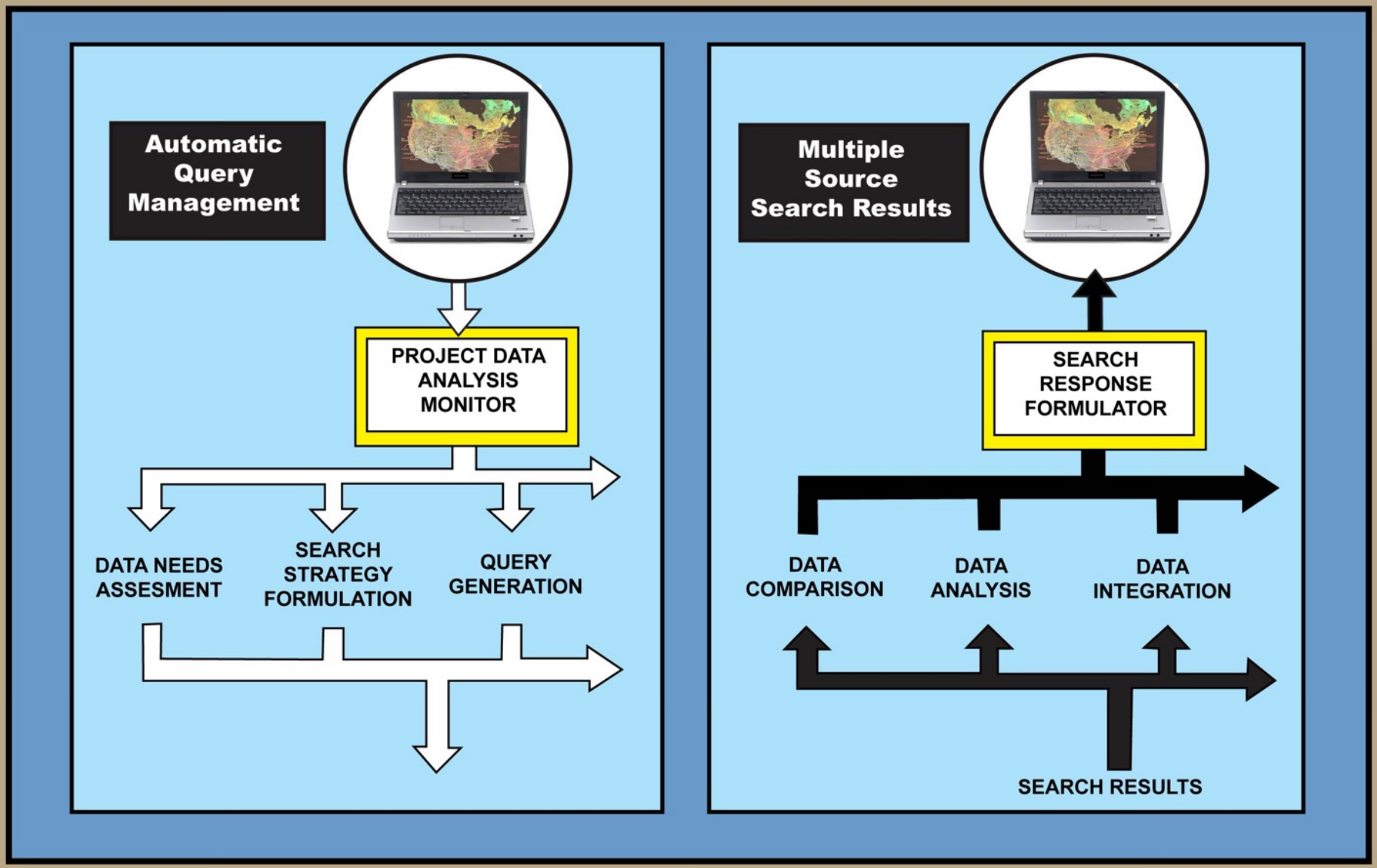
Design Environment Requirements

Multiple Data Source Searches



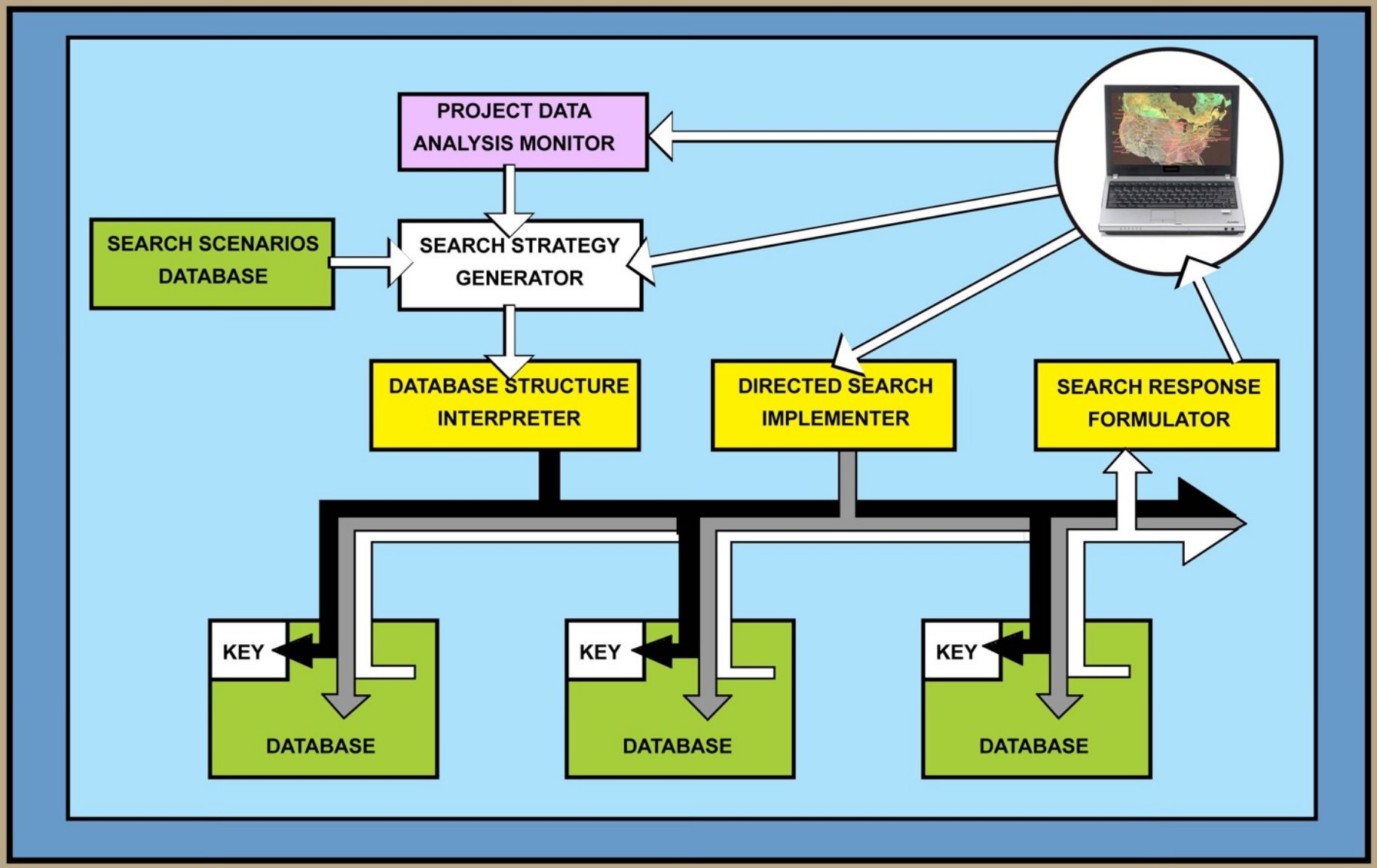
Design Environment Requirements

Automated Data Fusion



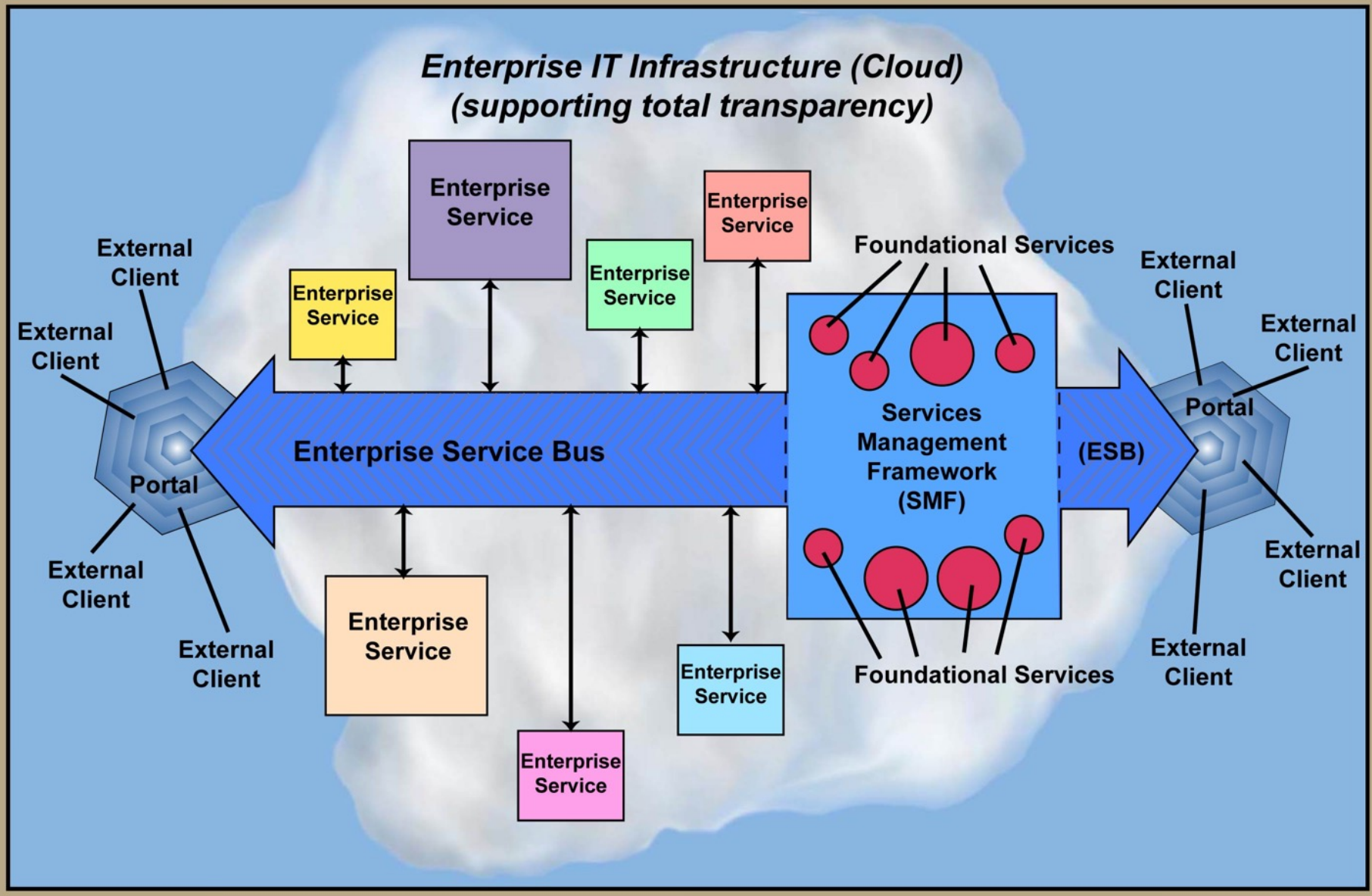
Design Environment Requirements

Conceptual Semantic Search Service



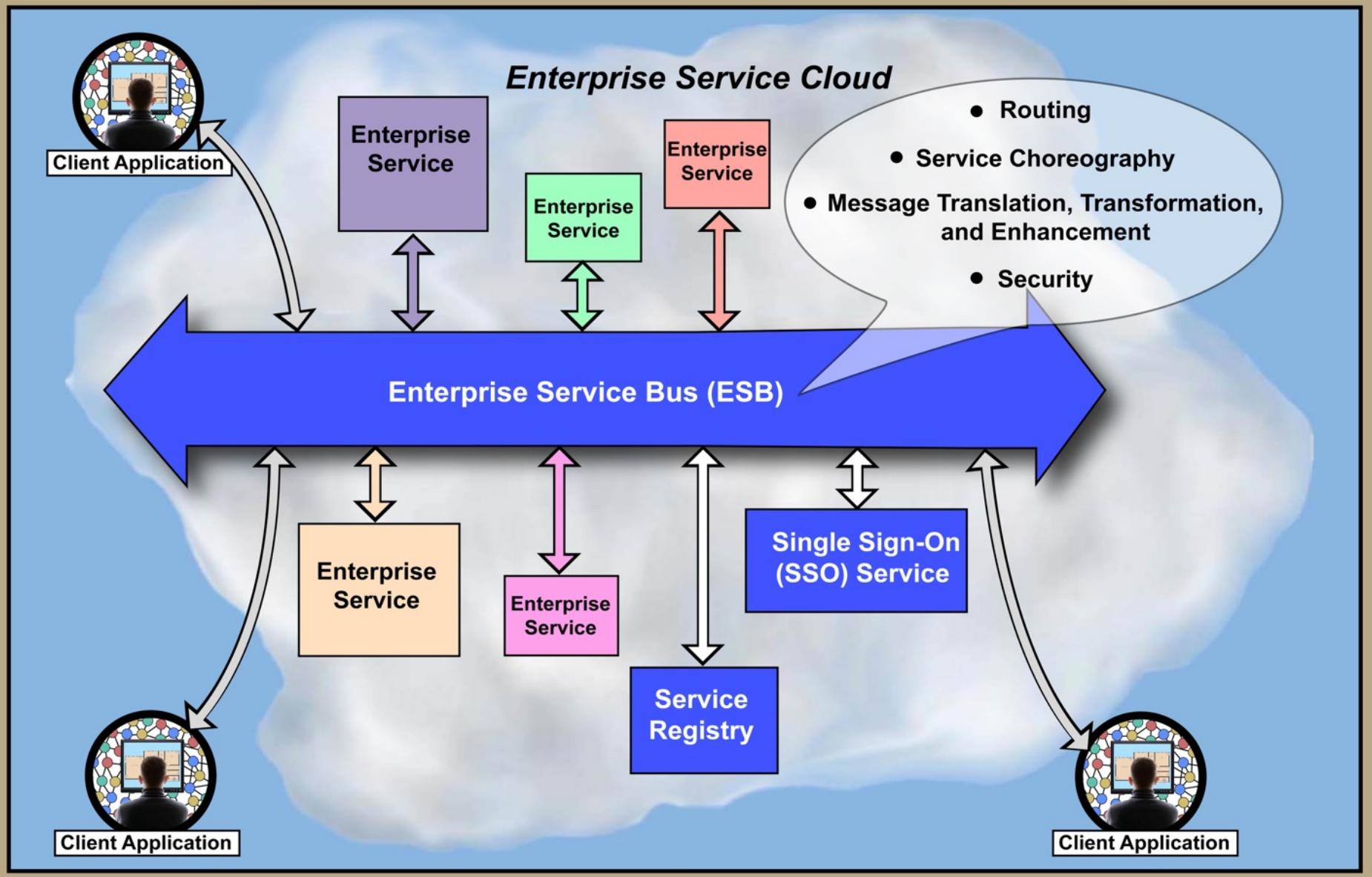
Technical Approach

Service-Oriented Architecture (SOA)



Intelligent Design Environment

Enterprise Service Bus (ESB) Functions



Technical Approach

Services Management Framework (SMF)

SMF is a SOA-based software infrastructure that utilizes tools (i.e., *foundational services*) to manage the exchange of messages among enterprise services. The messages may contain service request information, data, service response information, or any combination of these.

- Must be capable of undertaking any *transformation*, *orchestration*, *coordination*, and *security* actions necessary for the effective exchange of messages.
- Must be capable of maintaining a *loosely coupled* environment in which neither service requestors nor service providers need to communicate directly with each other (*or have knowledge of each other*).

A SMF may accomplish some of its functions through an ESB, or it may be implemented entirely as an ESB.

Technical Approach

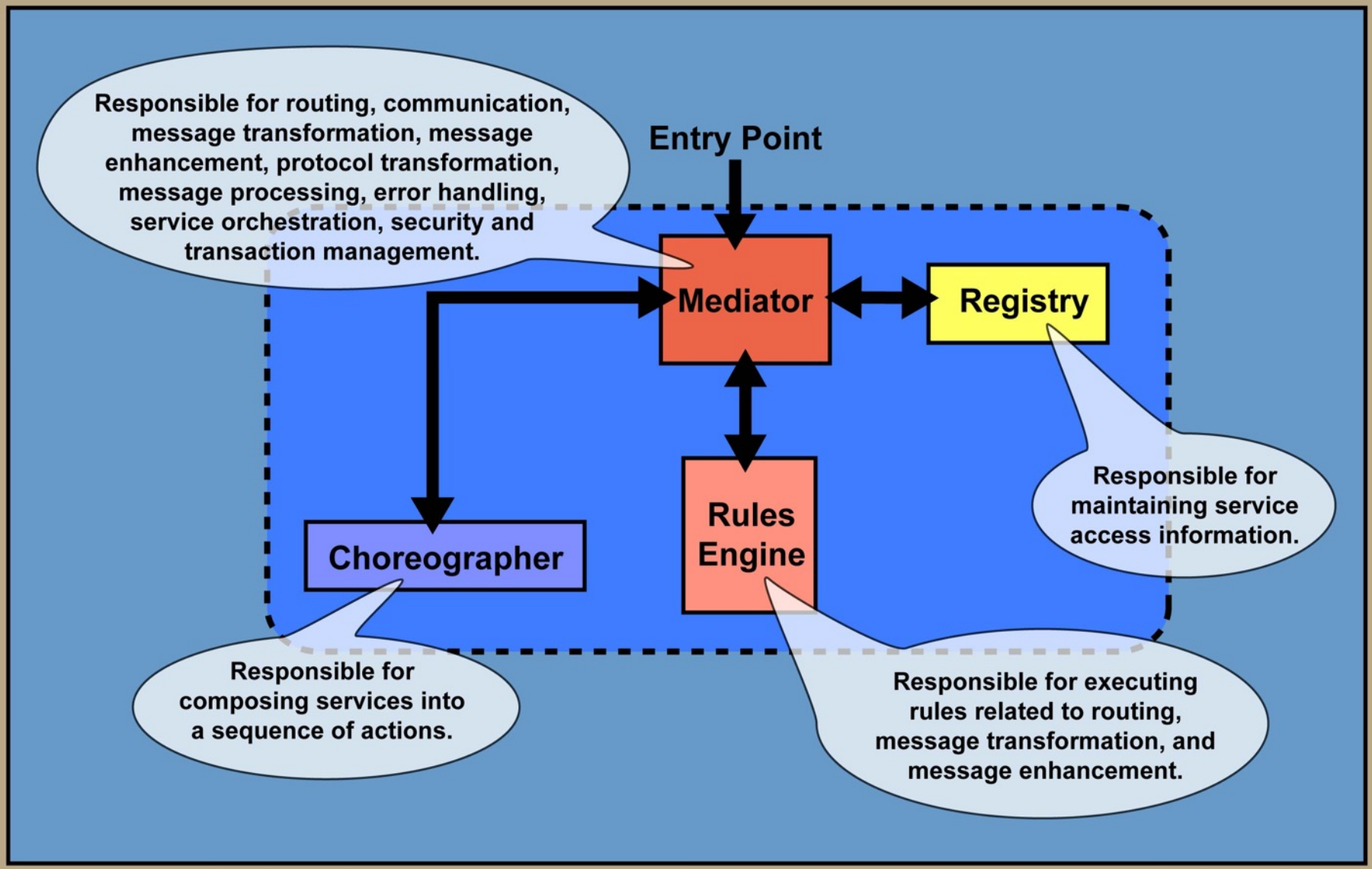
Enterprise Service Bus (ESB)

The concept of an ESB greatly facilitates SOA implementations by providing specifications for the coherent management of services. There are several commercial off-the-shelf (COTS) implementations that perform most ESB functions.

- ***Route*** **a request to a service provider.**
- ***Transform*** **sender-to-receiver** ***protocol*****.**
- ***Transform*** **the** ***format*** **of a message.**
- ***Choreograph*** **processes involving** ***multiple services*****.**
- ***Protect*** **services from** ***unauthorized access*****.**
- ***Coordinate*** **multiple resources across multiple disparate services.**

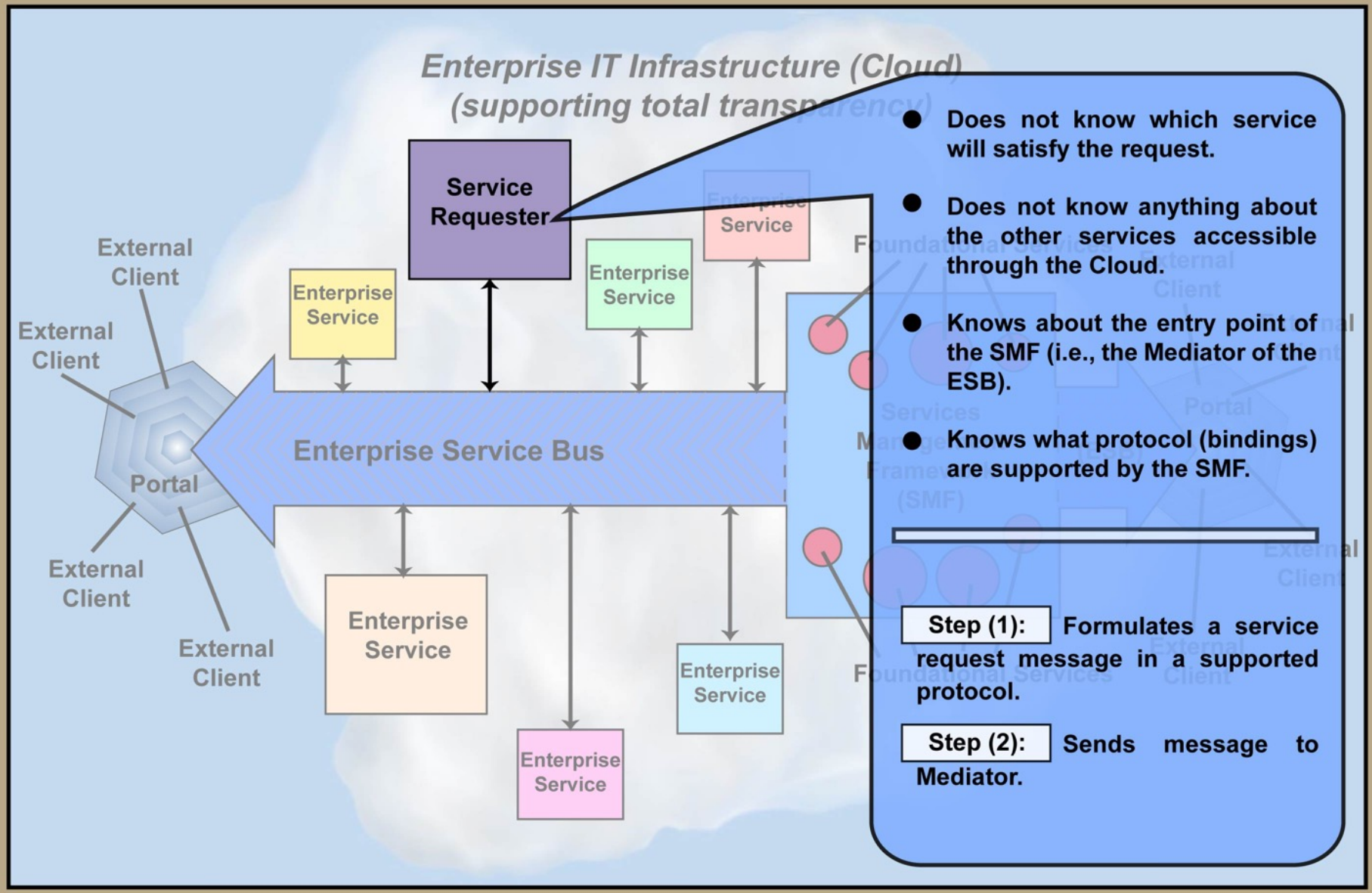
Technical Approach

ESB Principal Components



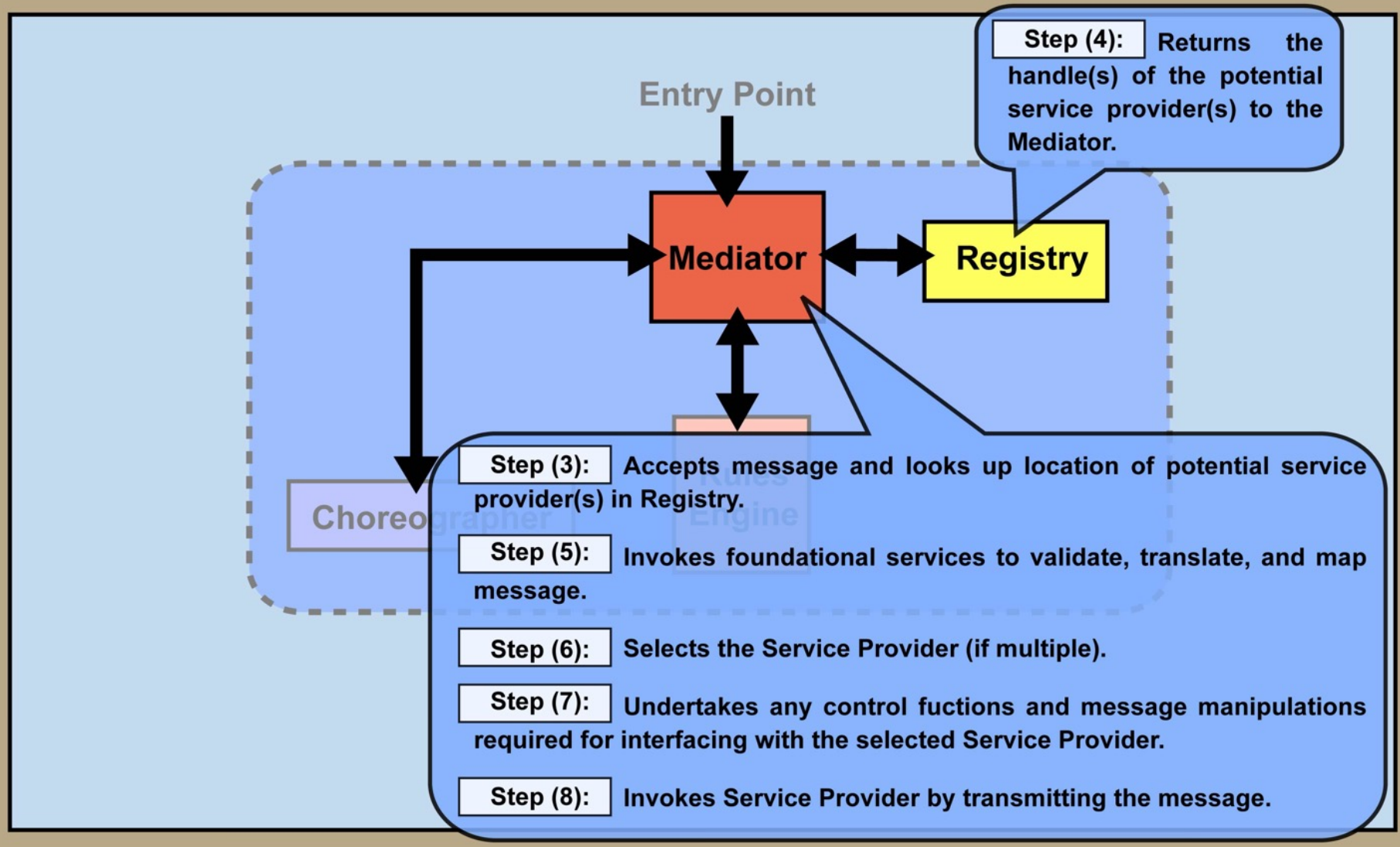
Design Environment Operations

Request for Services



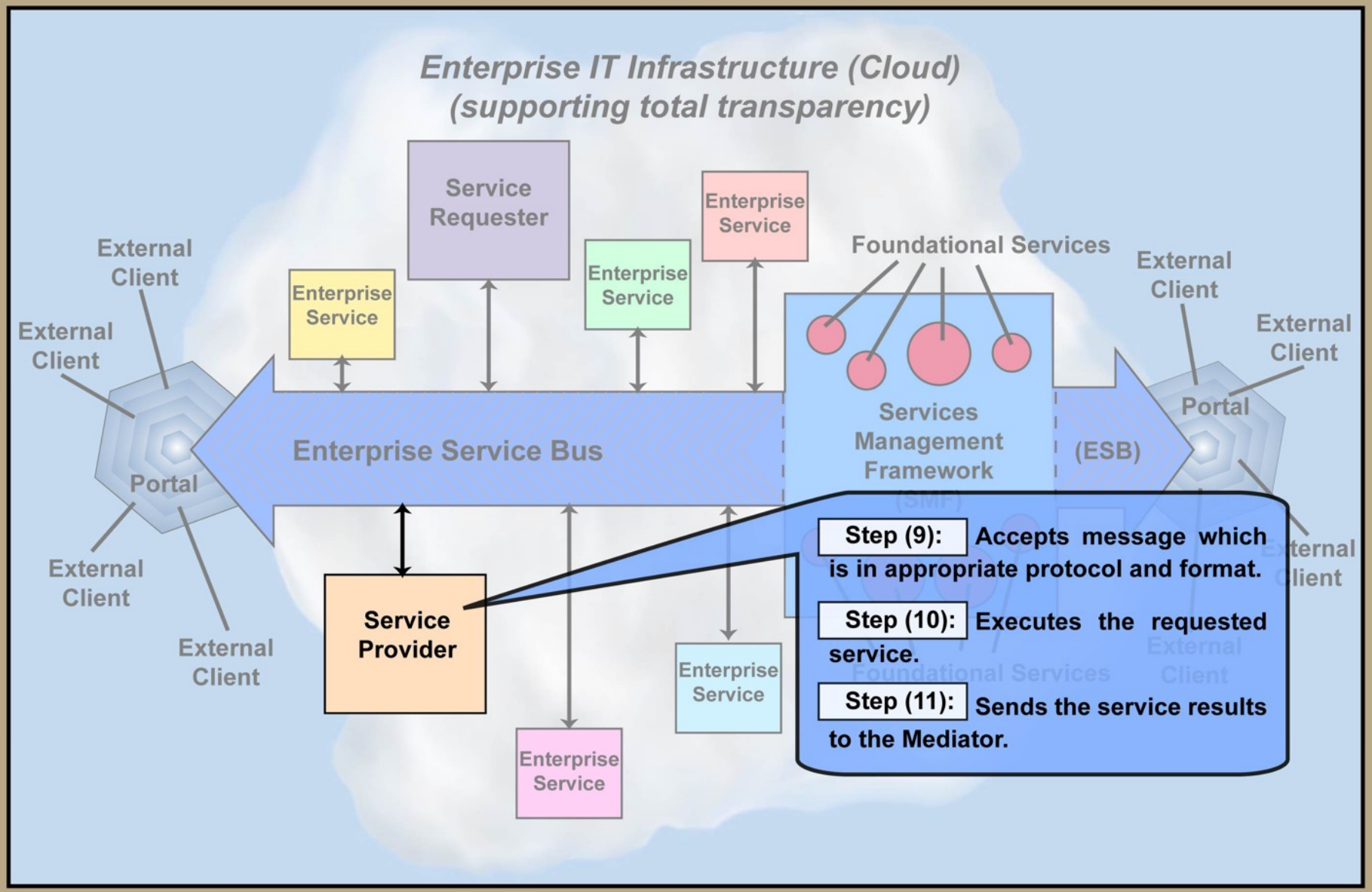
Design Environment Operations

Mediation of Service Request



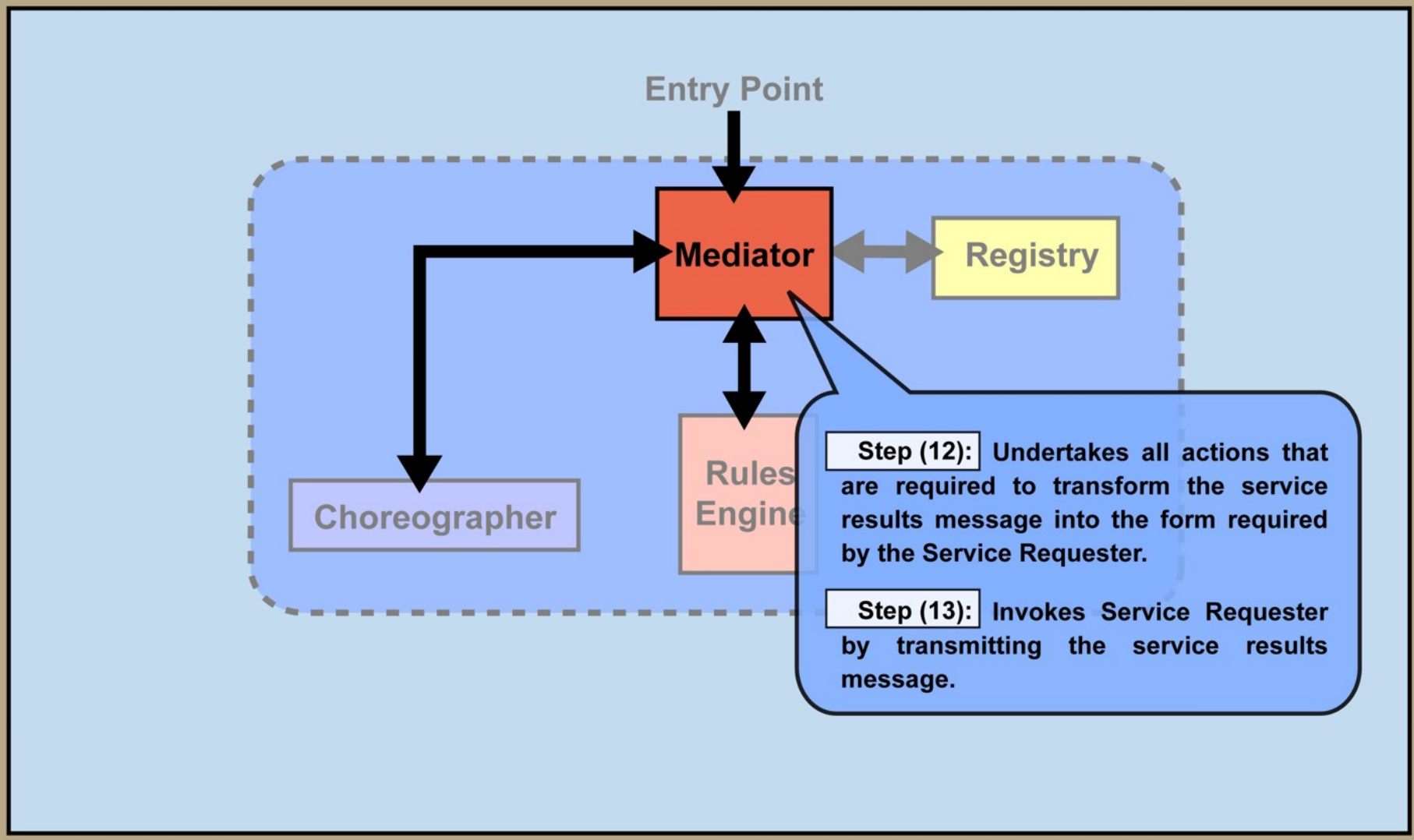
Design Environment Operations

Service Provider Response



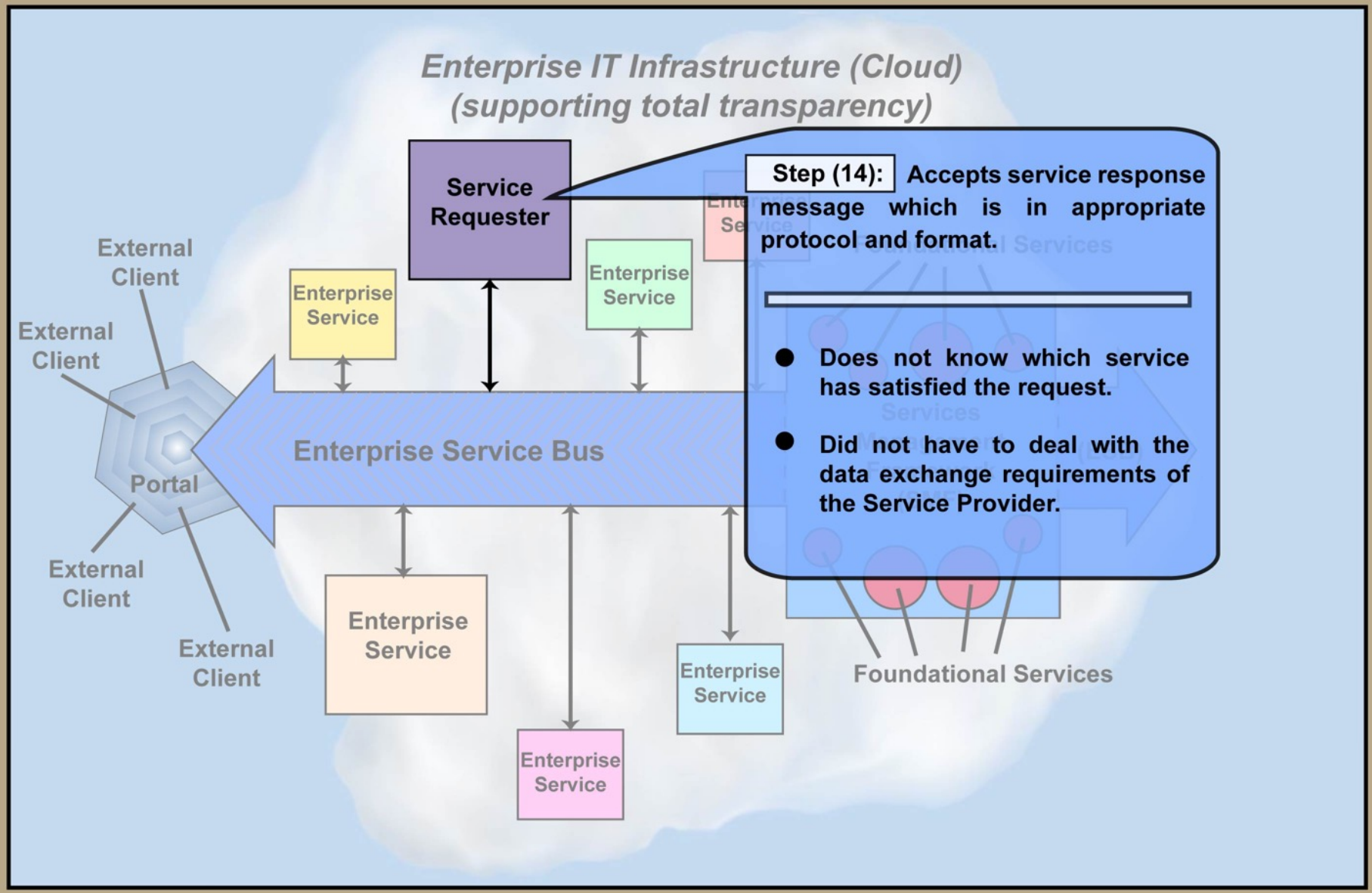
Design Environment Operations

Mediation of Service Response



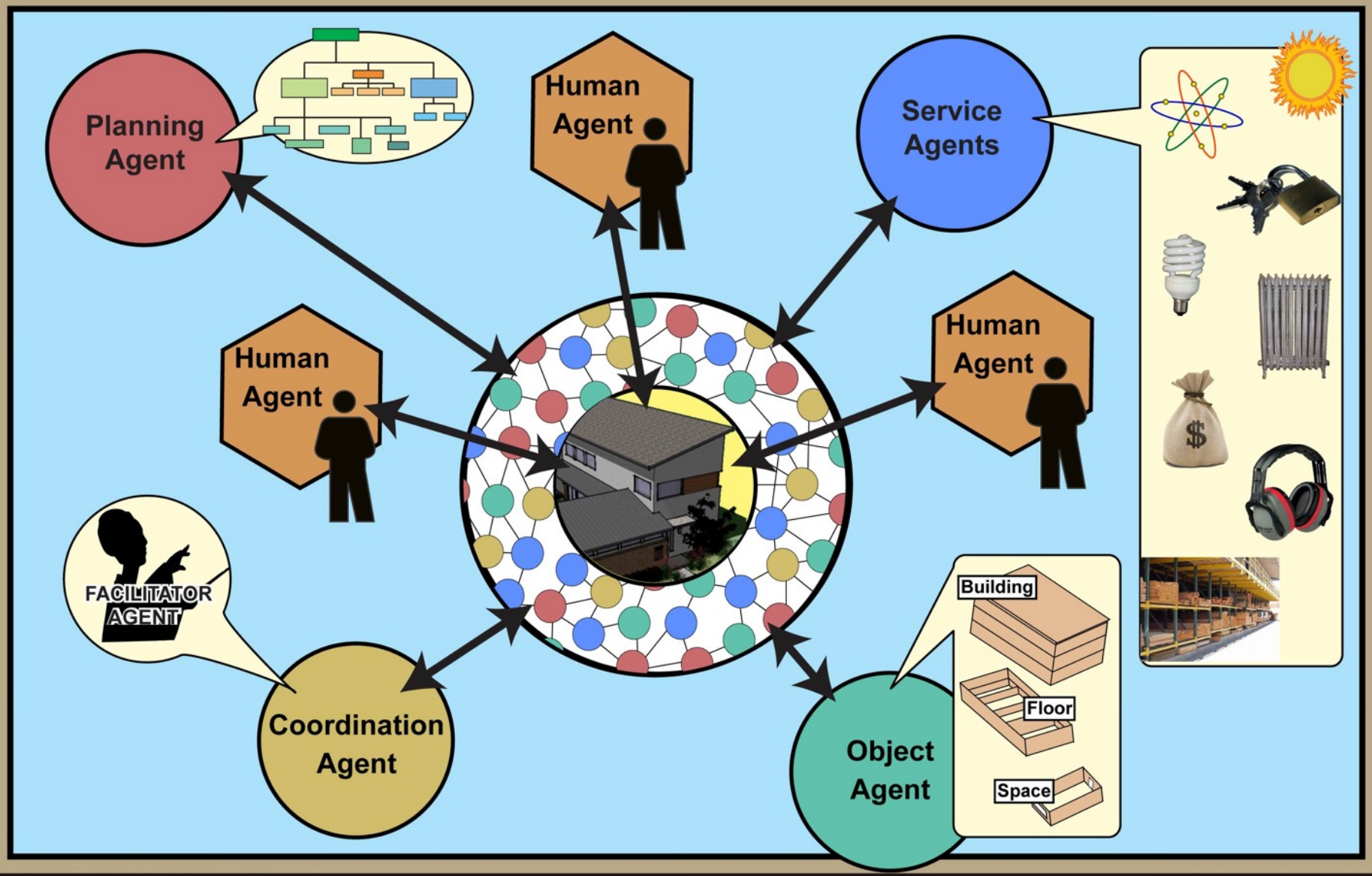
Design Environment Operations

Satisfaction of Service Request



Design Environment Tools

Collaborative Agent Types



Intelligent Design Environment

External User-Interface: Designer's View

Design Environment Tools

Service Agents

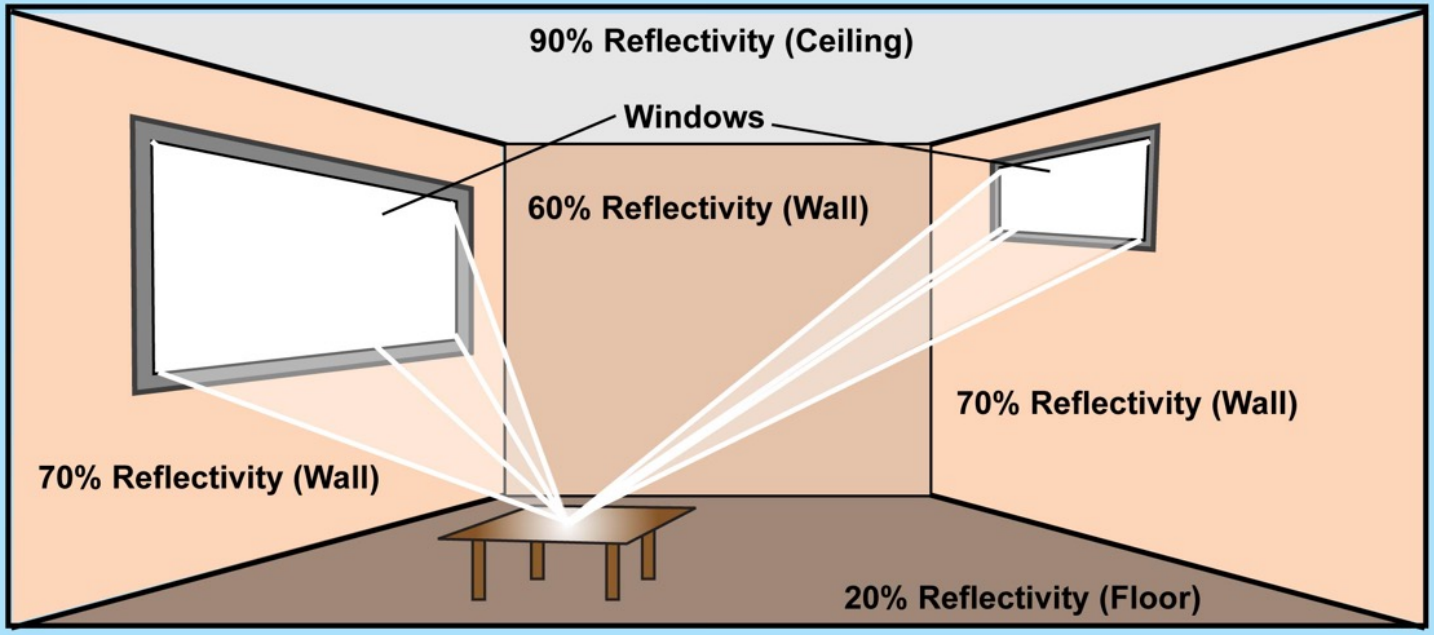
Service Agents **have analysis capabilities and knowledge in *narrow* design domains such as structural systems, daylighting, and artificial lighting, noise control, solar systems, material selection, and construction costs.**

- **May *provide services* to *other agents* as well as the human designer(s).**
- **Are *triggered* by the state of the evolving design solution within the internal representation of *context*.**
- **Have *alerting* and *explanation* facilities.**
- **May broadcast *requests* for services to *other agents*.**
- **Can also undertake *proactive explorations* opportunistically.**

Design Environment Tools

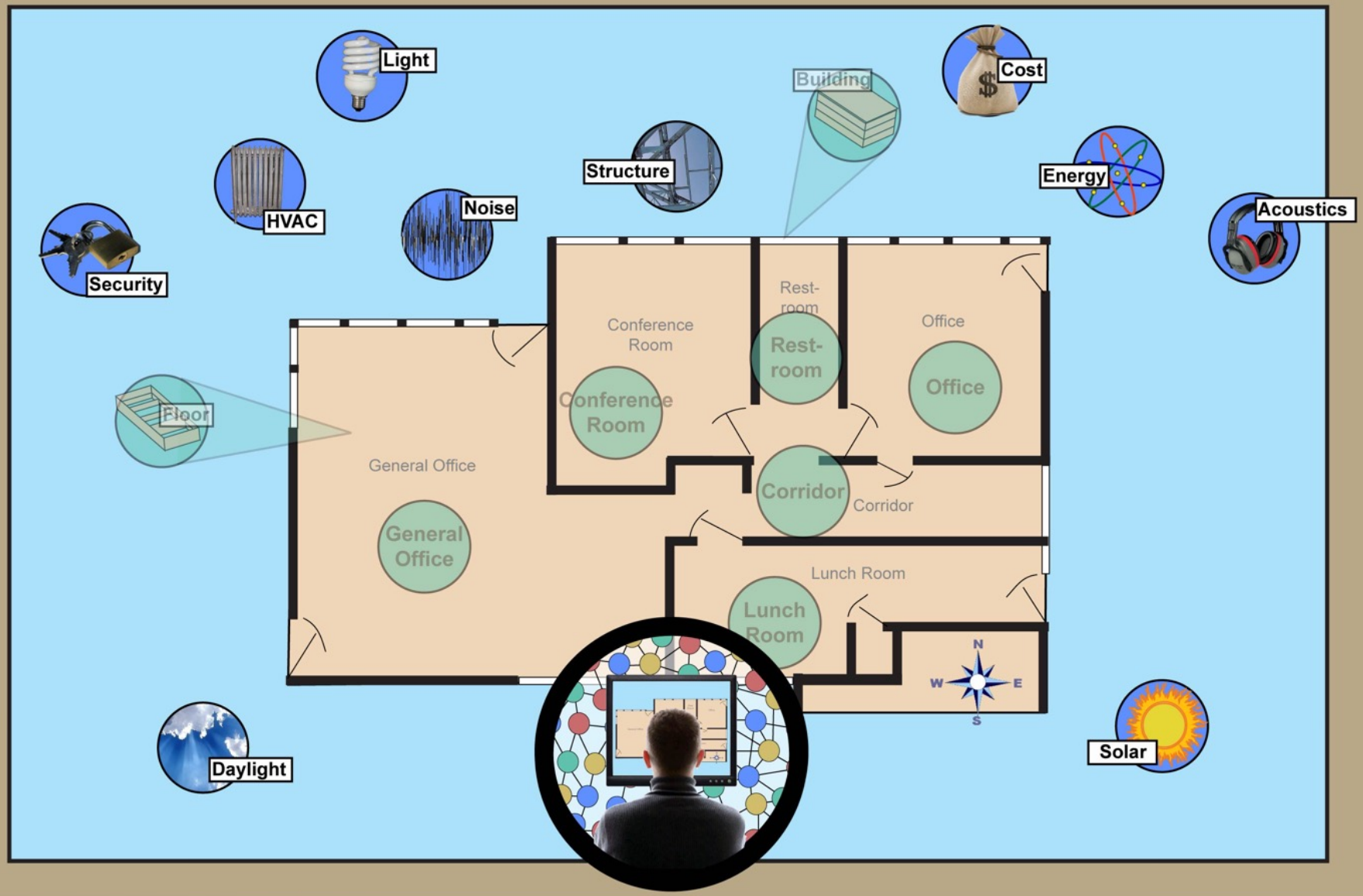
Typical Service Agent

Daylighting Agent **is capable of estimating the illumination level due to daylight at any point within a building space based on the geometry and reflectivities of the space and the properties of any translucent external openings.**



Intelligent Design Environment

Internal Tools: Service Agents



Design Environment Tools

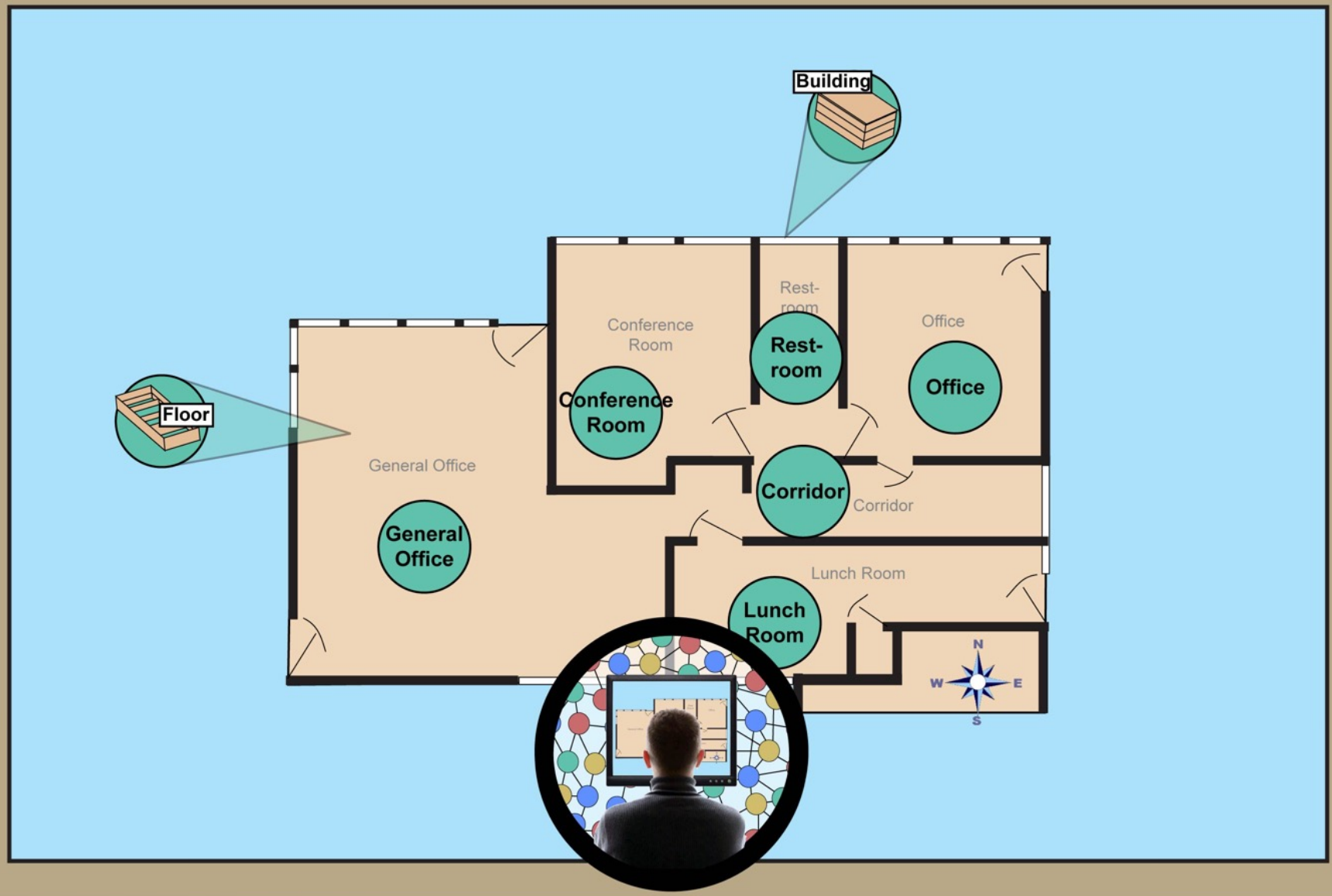
Object Agents

Object Agents **represent the interests of *building components* such as openings (windows and doors), space, building floors, and the building itself, based on the description of their characteristics and relationships in the internal *context* model.**

- **Have *needs* based on their *functional purpose*.**
- **Are able to *orientate* themselves geometrically (*location*) and hierarchically (*importance*) within the current state of the design solution.**
- **Will broadcast *requests* for services to *Service Agents*.**
- **May *negotiate* directly with other *Object Agents*.**
- **Can pursue interests *proactively* leading to *alternative* design solutions.**

Intelligent Design Environment

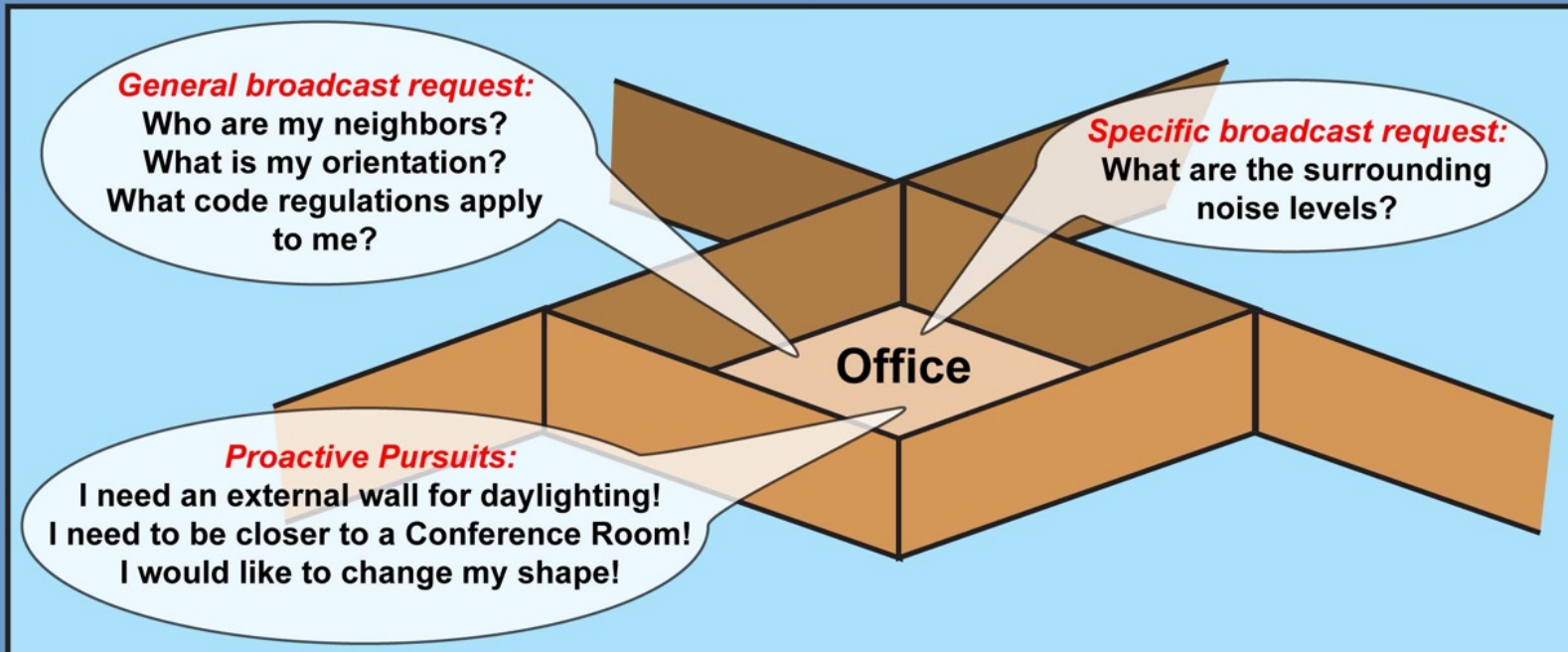
Internal Tools: Space Agents



Design Environment Tools

Typical Object Agent

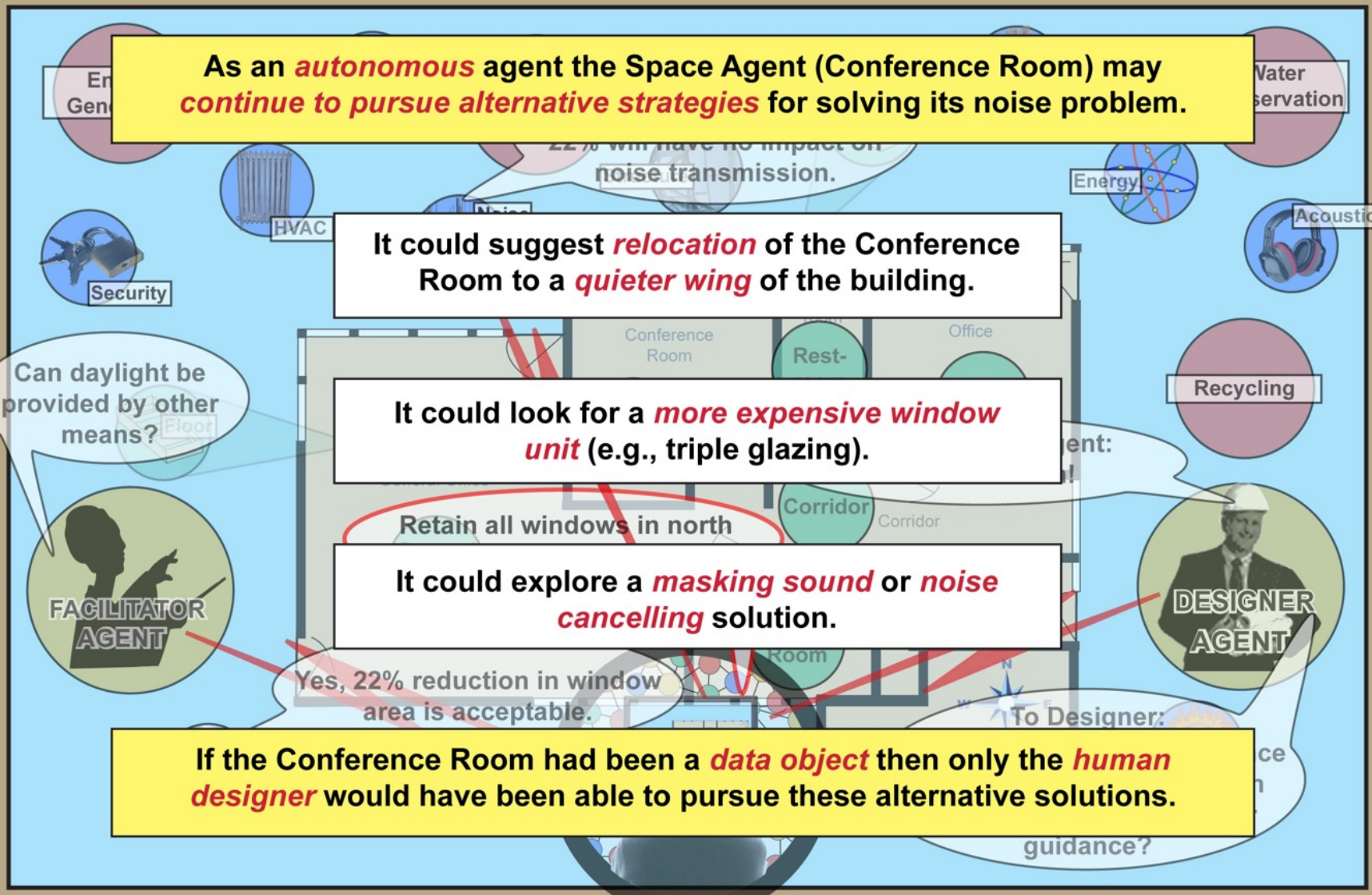
Space Agents represent the ***interests*** of a ***particular space*** (e.g., office, conference room, lobby) based on the requirements (e.g., dimensions, daylight, privacy) and relationships (to other spaces) represented in the internal ***context*** model.



After the human designer has added an office space to the evolving floor plan, the interests of the office are represented by the ***Office Agent***.

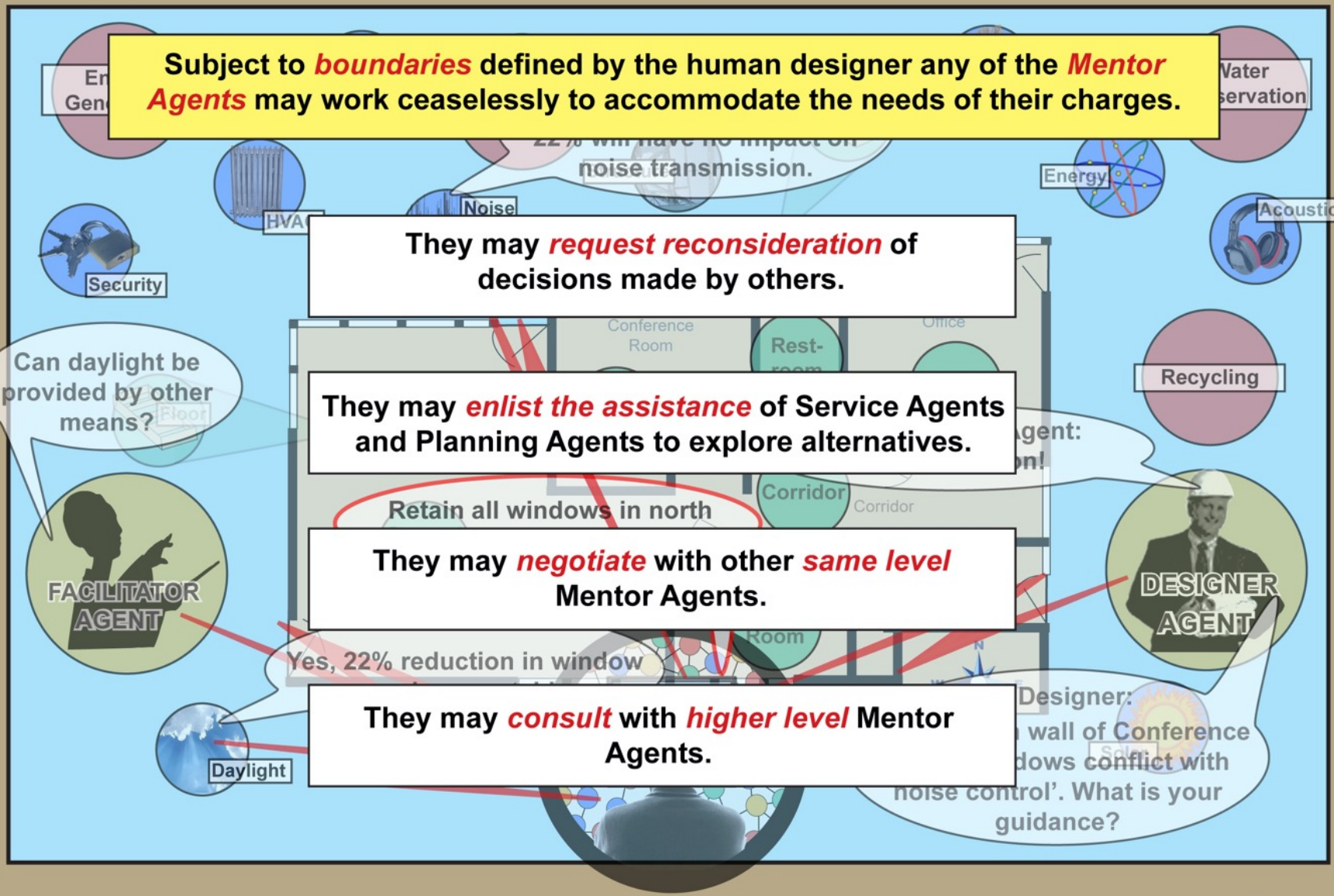
Intelligent Design Environment

Continuing Space Agent Actions



Intelligent Design Environment

Mentor Agent Opportunities



Design Environment Tools

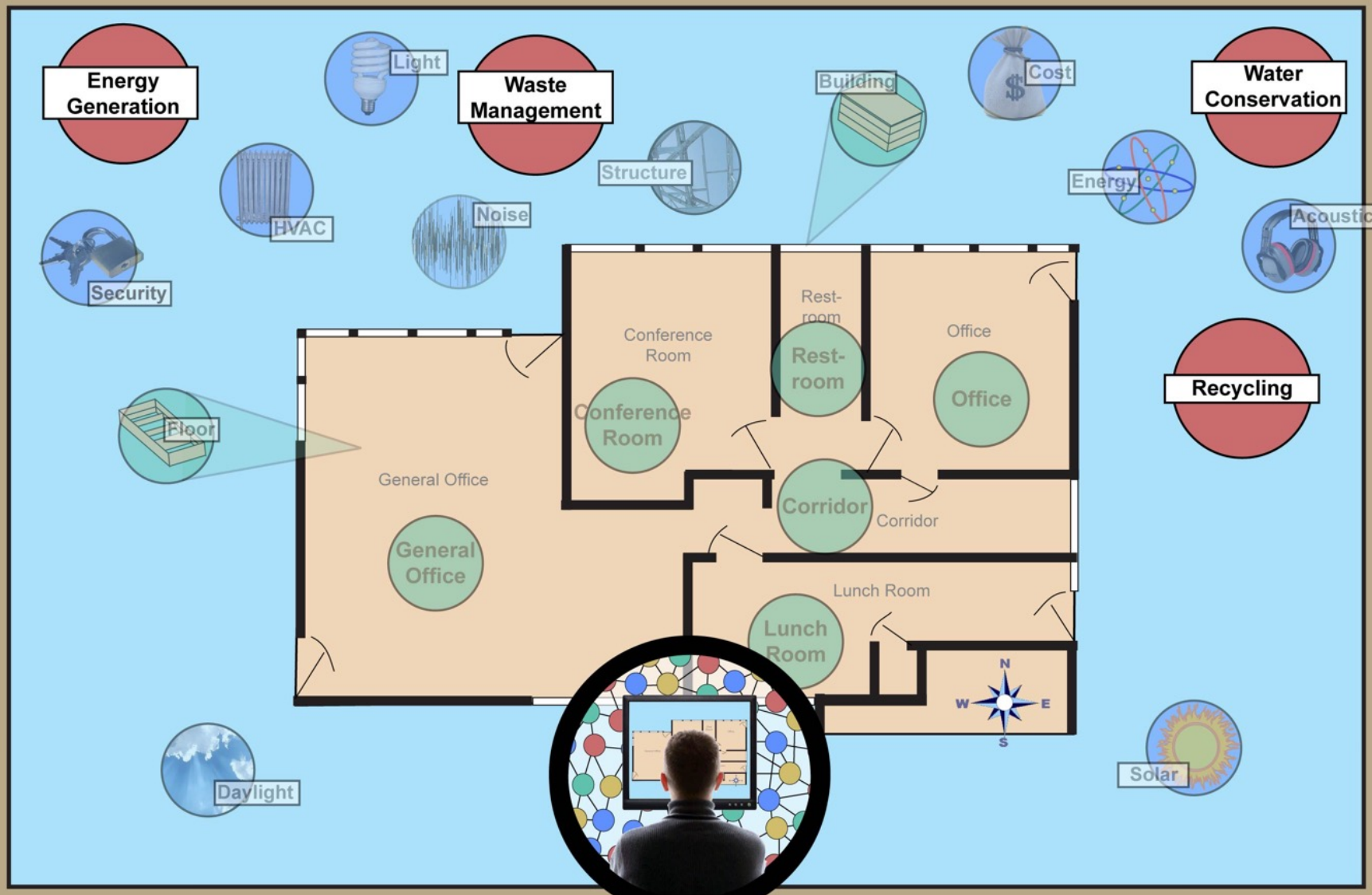
Planning Agents

Planning Agents **deal with *broader* issues that relate to the ability of the evolving solution to meet *design criteria* such as energy conservation, minimum freshwater usage, recycling, maintainability, and electricity generation.**

- **Are capable of *orchestrating* evaluations involving *several* Service Agents.**
- **Can provide *overall state-of-design assessments* on request or by alert.**
- **May be *tasked* by the human designer or Coordination Agents.**
- **Are able to *request* services from *Service Agents*.**
- **Will become *more* active during the *later* design stages.**

Intelligent Design Environment

Internal Tools: Planning Agents



Design Environment Tools

Typical Planning Agent

Energy Generation Agent **will monitor the evolving design solution to *explore opportunities* for the building to become a zero-energy-consumer or net-energy-producer.**

This will involve the *coordination* of multiple *Service Agents* in:

- **Assessing the *energy generation opportunities* of the site and building type.**
- **Estimating the annual *post-occupancy* electricity consumption.**
- **Exploring the electricity savings achievable through *solar heating*.**
- **Projecting the *photovoltaic (PV)* electricity generation potential.**
- **Determining the *life cycle cost* of alternative proposals.**

Design Environment Tools

Coordination Agents

Coordination Agents **are responsible for** ***conflict detection*** **and for ensuring that the final design solution meets the** ***performance targets*** **implied by the design criteria.**

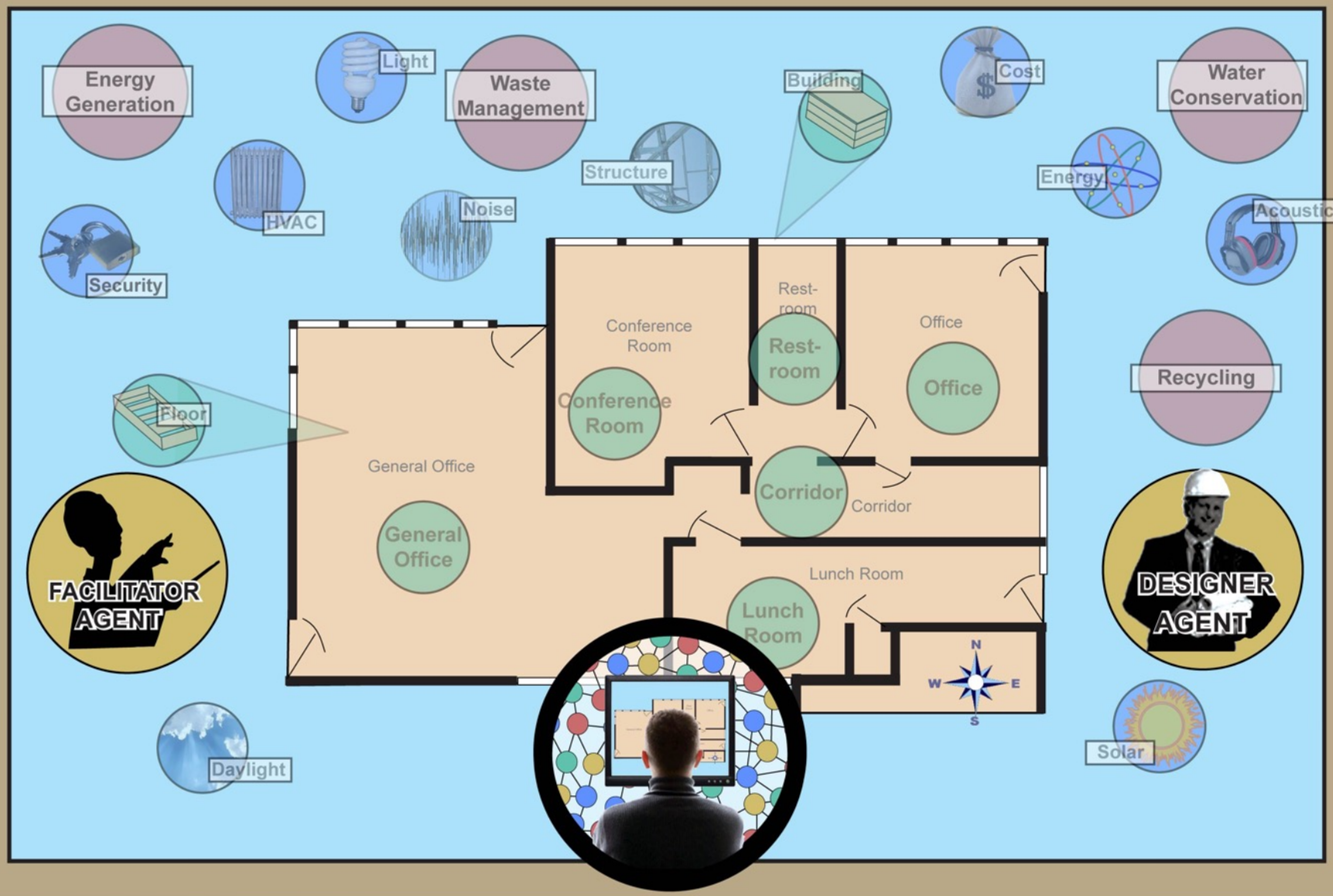
Conflict Resolution **involves the detection of a conflict, identification of the causes, and exploration of potential conflict resolution strategies by a** ***Facilitator Agent*****.**

Performance Assessment **involves the continuous monitoring of the evolving solution by the** ***Designer Agent*****, in terms of its ability to meet the intent of the human designer.**

Coordination Agents require the ***most intelligence*** **because they need to assess the impact of individual decisions in many domains on the ability of the holistic design solution to meet the expectations of the designer.**

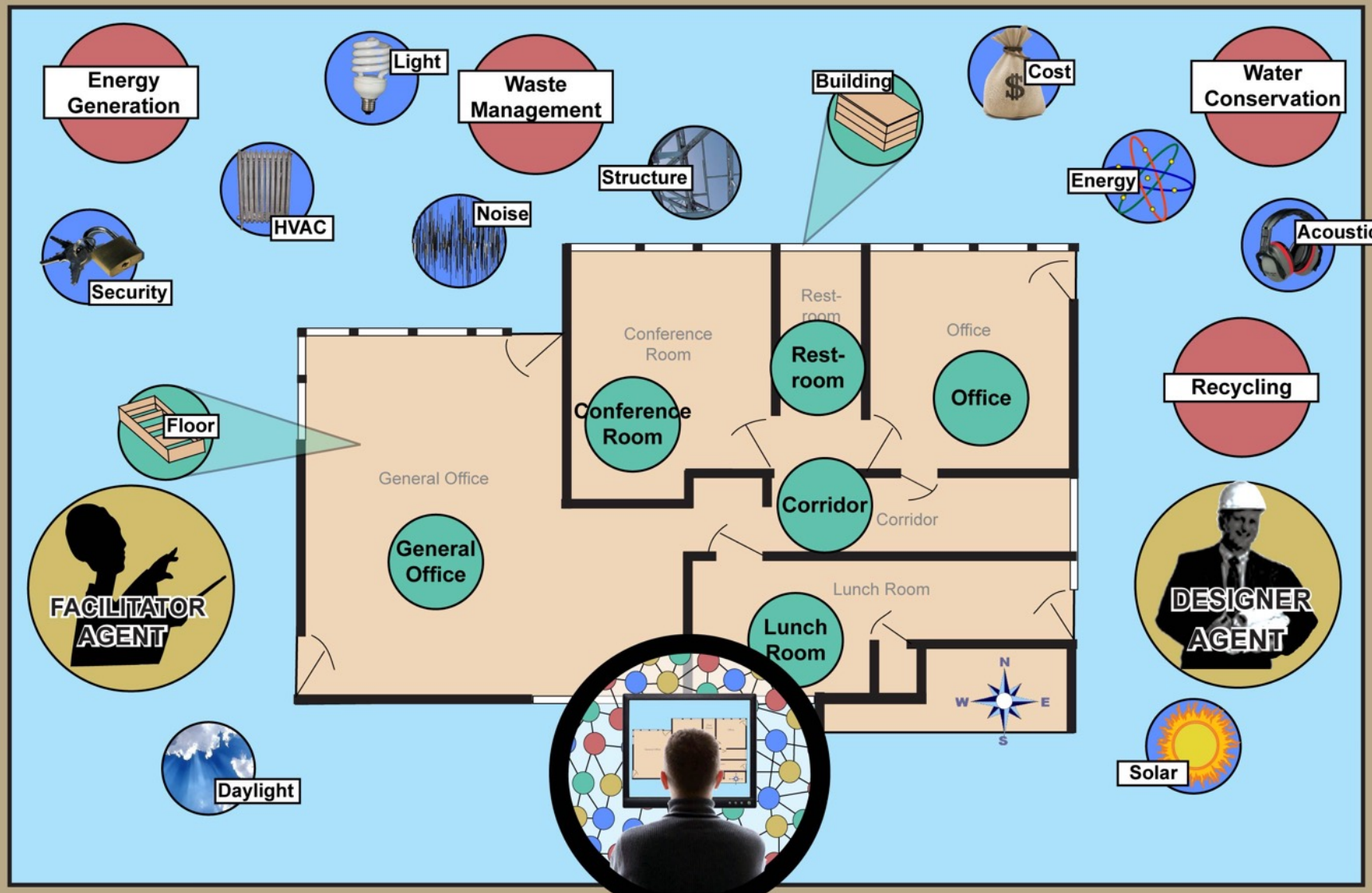
Intelligent Design Environment

Internal Tools: Coordination Agents



Intelligent Design Environment

Human-Computer Partnership



Intelligent Design Environment

Concluding Assessment

Key Requirements	Technology	
(A) Internal virtual *design context* model.	Ontology of the design knowledge domains.	✓
(B) *Intelligent* monitoring, search, evaluation, planning, explanation, and coordination *tools*.	Service Agents Planning agents Mentor Agents Coordination Agents	✓ ✓ ✓ ✓
(C) Comprehensive *human-computer partnership* support.	Semantic Search Explanation 2D-3D graphics Virtual Reality	✓ ✓ ✓ ?
(D) Seamless user-interface that allows designer *to focus on the design activity* rather than the underlying technology.	Service-Oriented Architecture (SOA) based infrastructure.	✓