SyDEVS Library

Framework Overview

Autodesk Research

April 2018

Classic Theory (1970s)

DEVS

From Wikipedia, the free encyclopedia

DEVS abbreviating **Discrete Event System Specification** is a modular and hierarchical formalism for modeling and analyzing general systems

...

Atomic DEVS [edit]

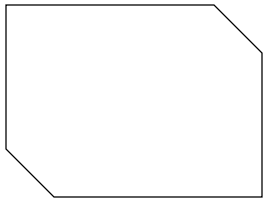
An atomic DEVS model is defined as a 7-tuple

$$M =< X, Y, S, ta, \delta_{ext}, \delta_{int}, \lambda >$$

where

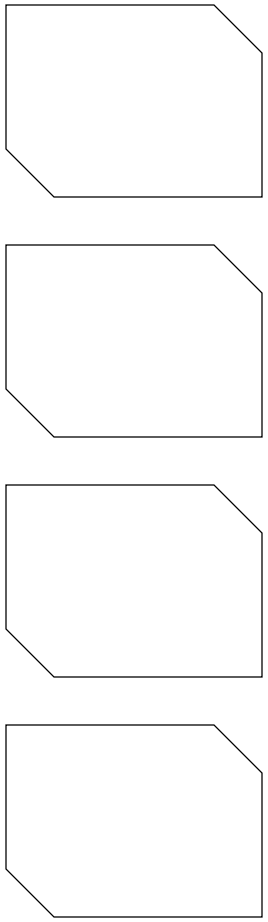
- X is *the set of input events*;
- Y is *the set of output events*;
- S is *the set of sequential states* (or also called *the set of partial states*);
- $s_0 \in S$ is *the initial state*;
- $ta : S \to \mathbb{T}^{\infty}$ is *the time advance function* which is used to determine the lifespan of a state;
- $\delta_{ext} : Q \times X \to S$ is *the external transition function* which defines how an input event changes a state of the system, where $Q = \{(s, t_e) | s \in S, t_e \in (\mathbb{T} \cap [0, ta(s)])\}$ is the *set of total states*, and t_e is the *elapsed time* since *the last event*;
- $\delta_{int} : S \to S$ is *the internal transition function* which defines how a state of the system changes internally (when the elapsed time reaches to the lifetime of the state);
- $\lambda : S \to Y^{\phi}$ is *the output function* where $Y^{\phi} = Y \cup \{\phi\}$ and $\phi \notin Y$ is a *silent* event or an *unobserved* event. This function defines how a state of the system generates an output event (when the elapsed time reaches to the lifetime of the state);

SyDEVS Approach



Simulation Node

SyDEVS Approach



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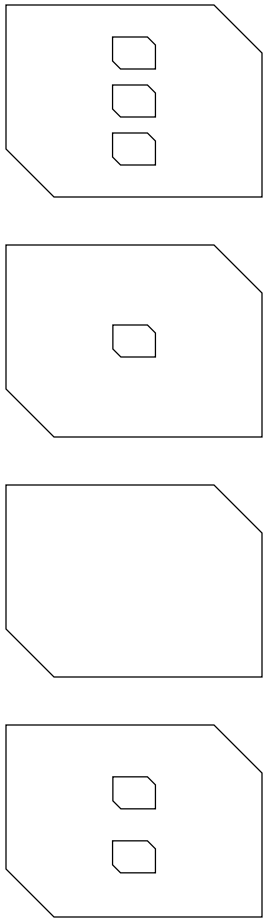

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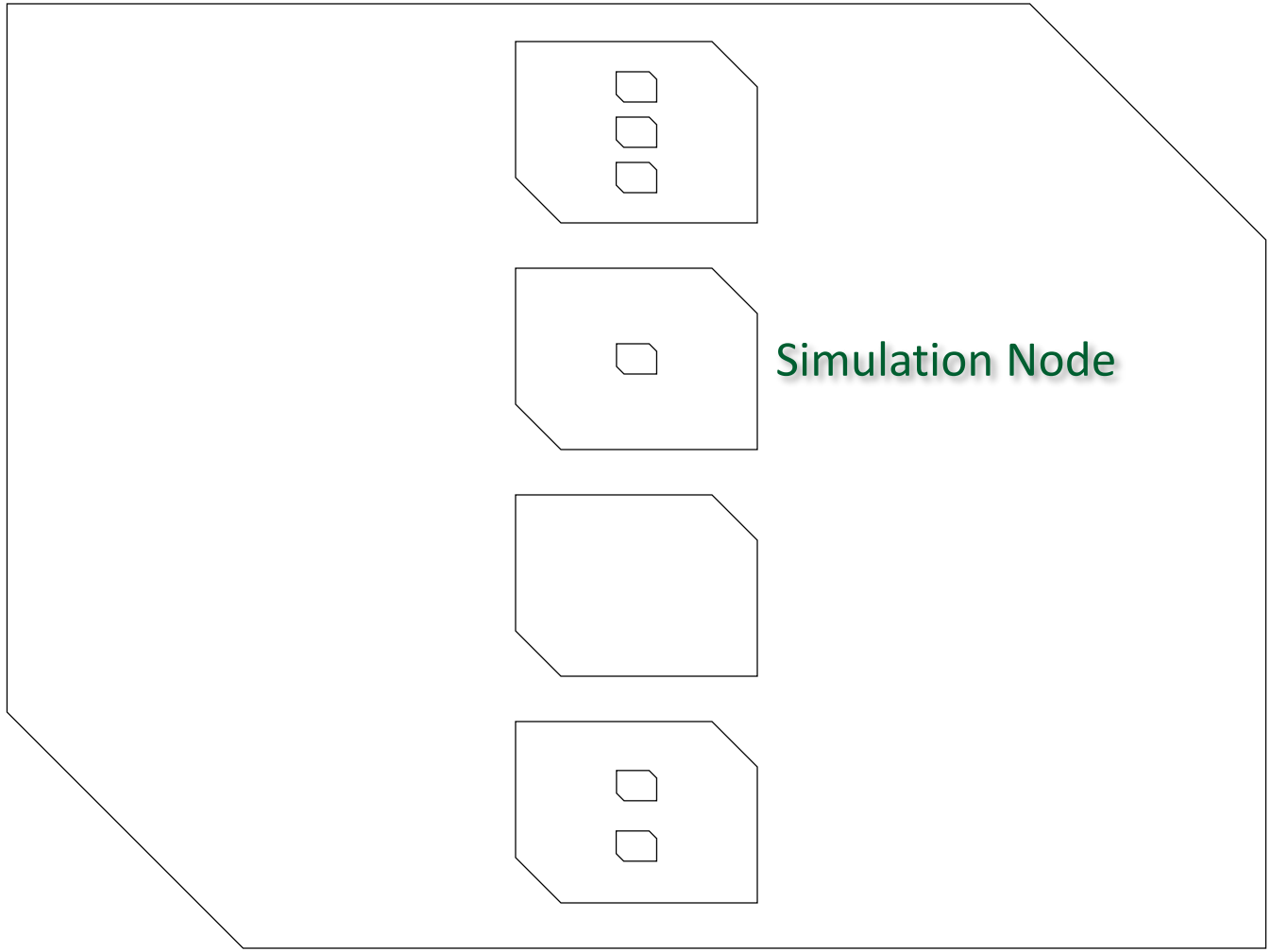

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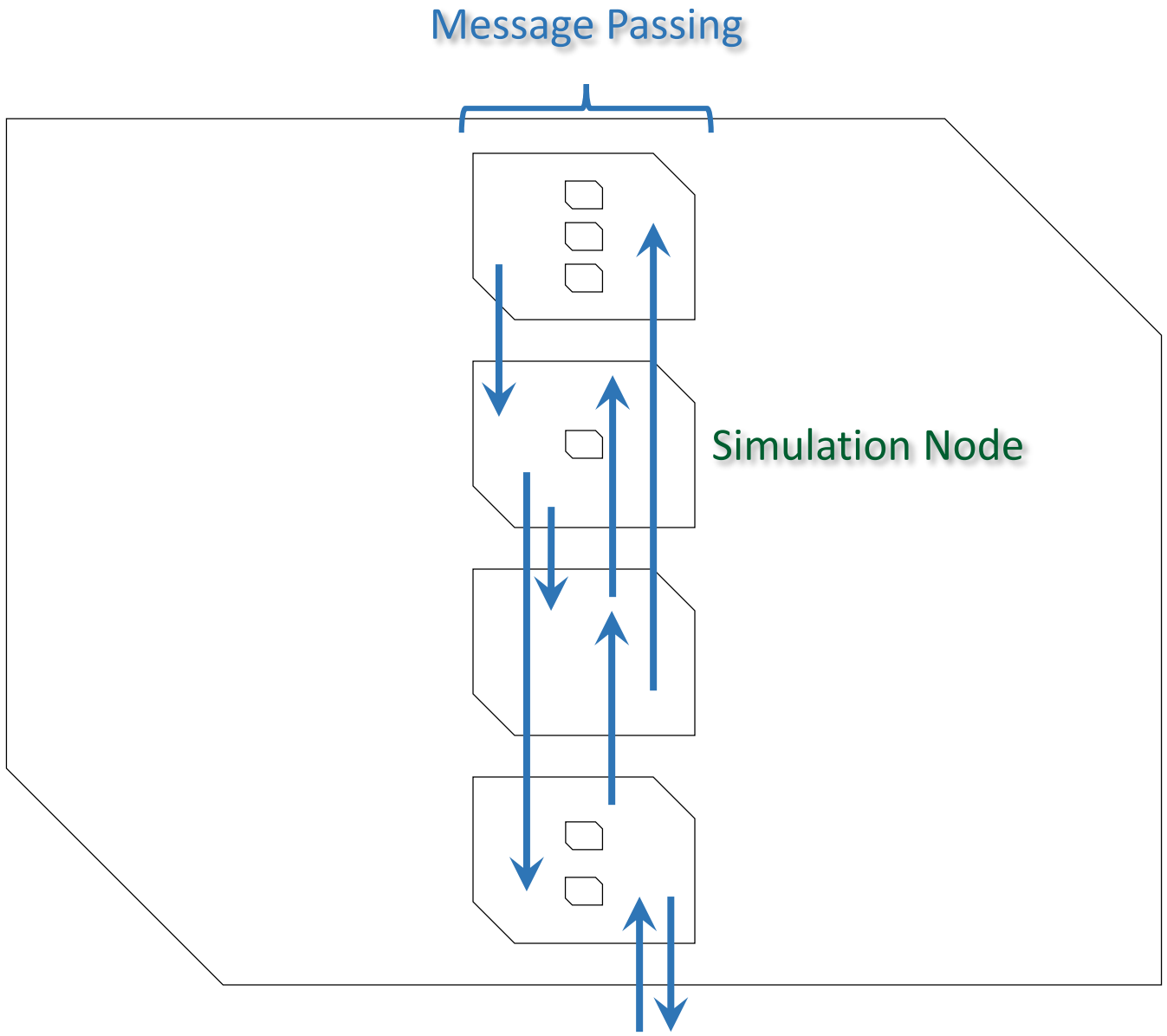

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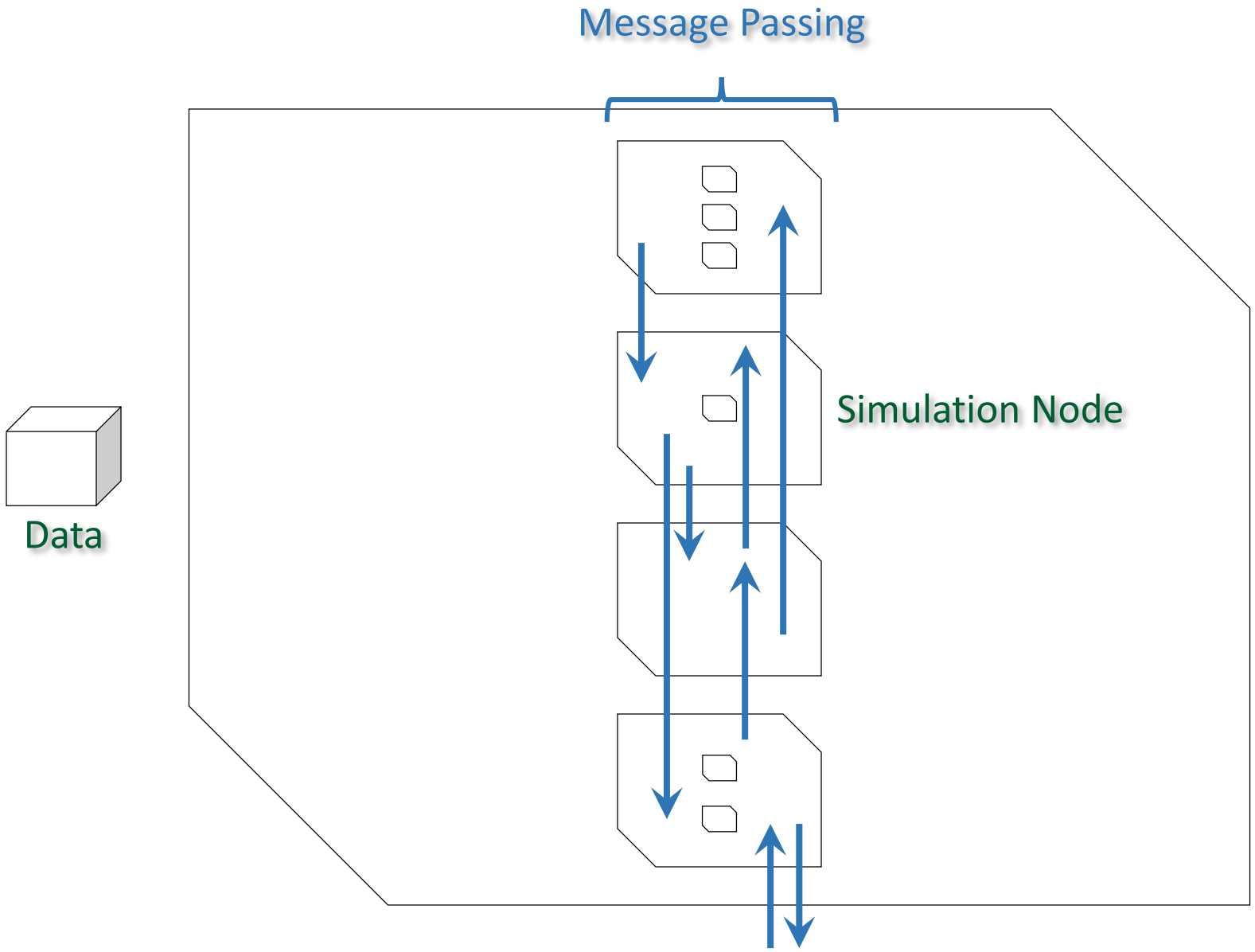

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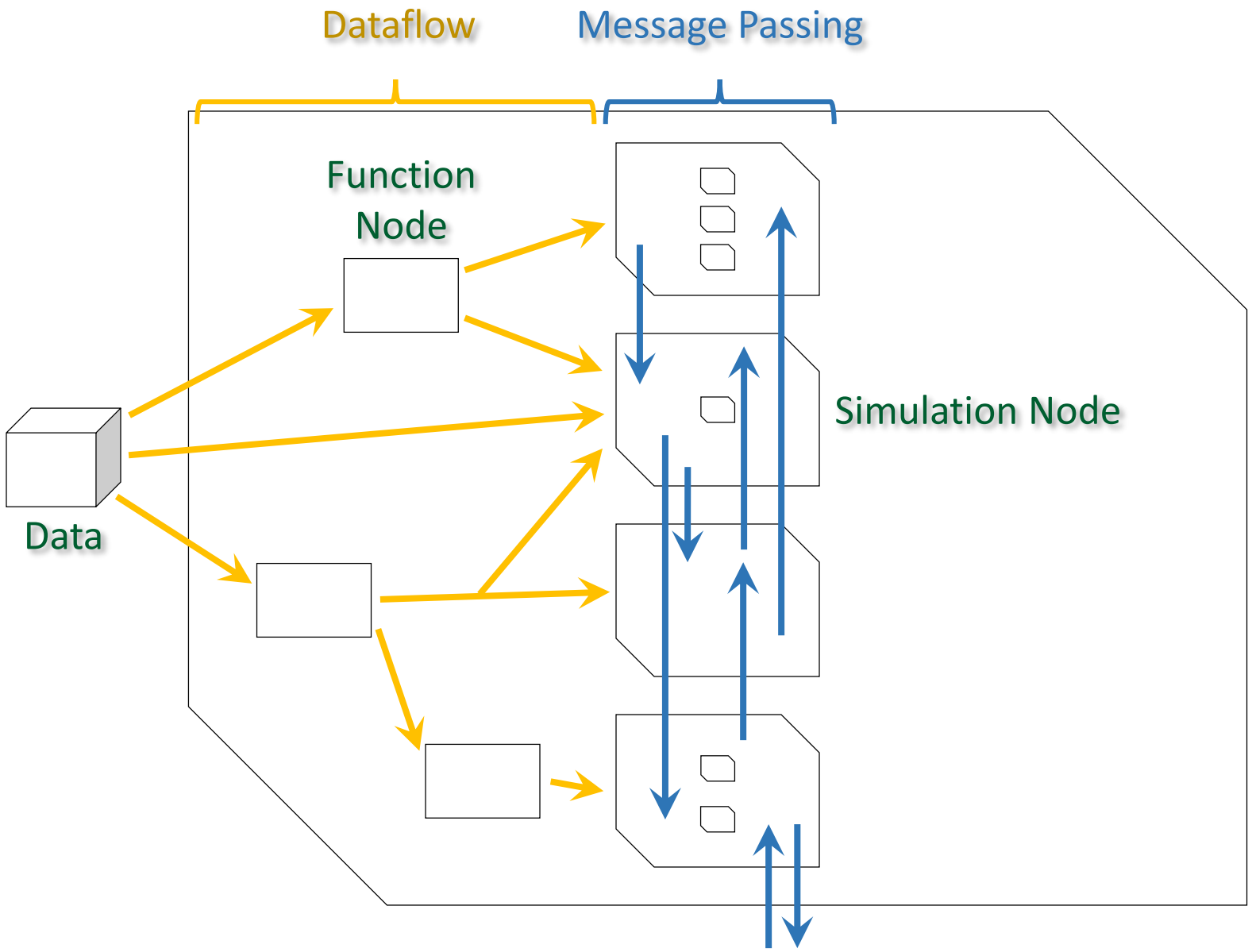

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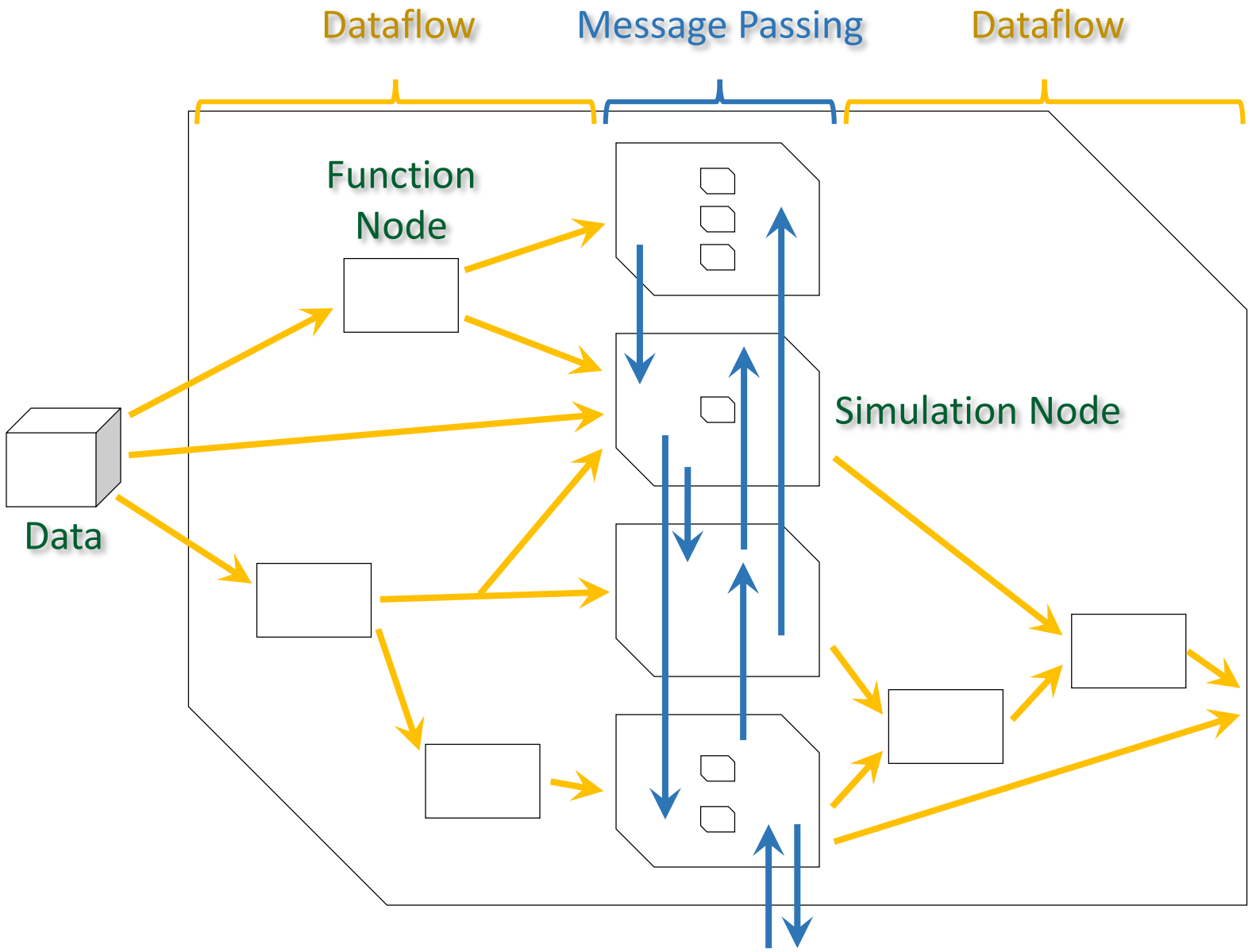

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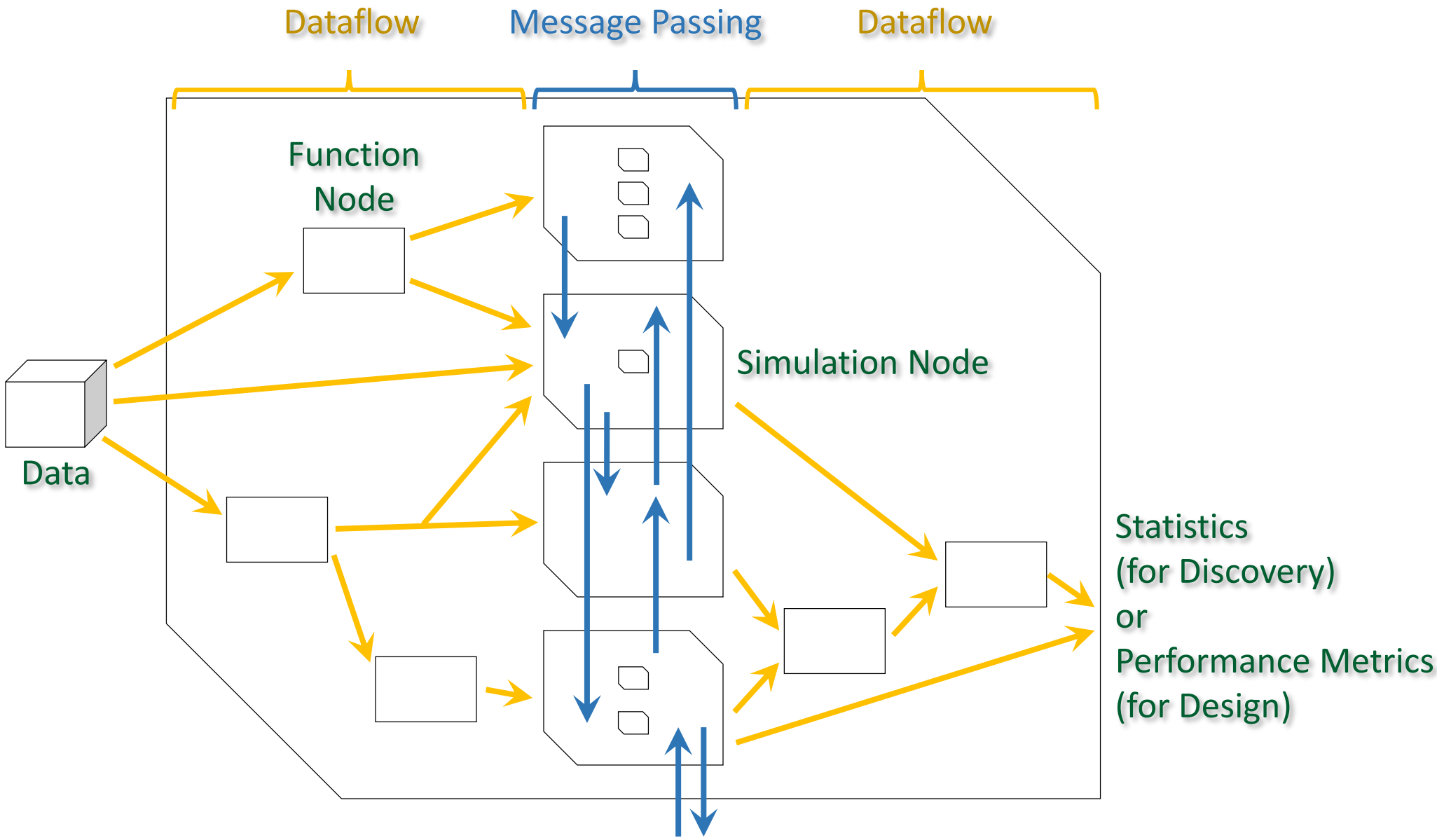
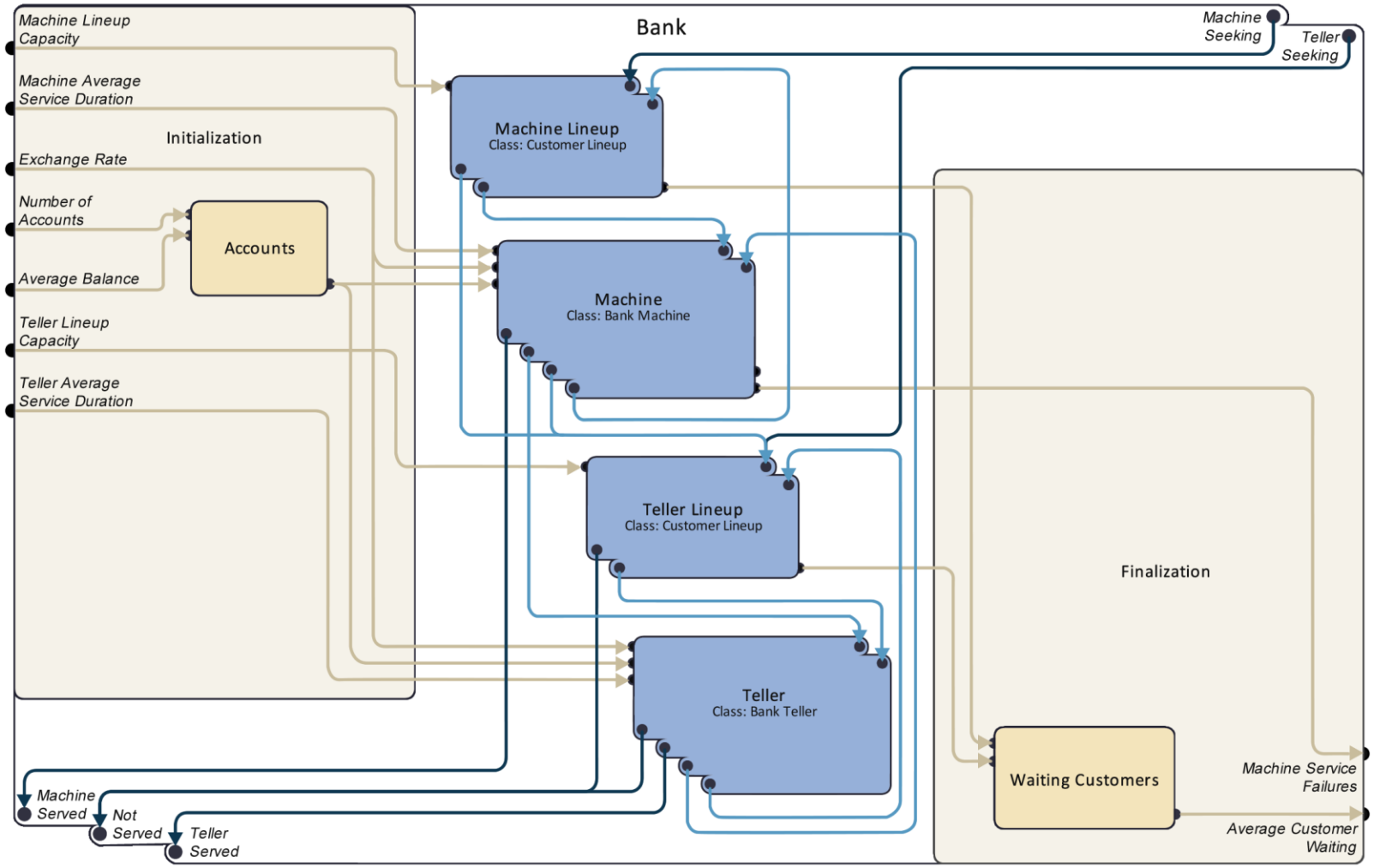


Proposed Visual Interface



https://autodeskresearch.com/publications/designingdevs

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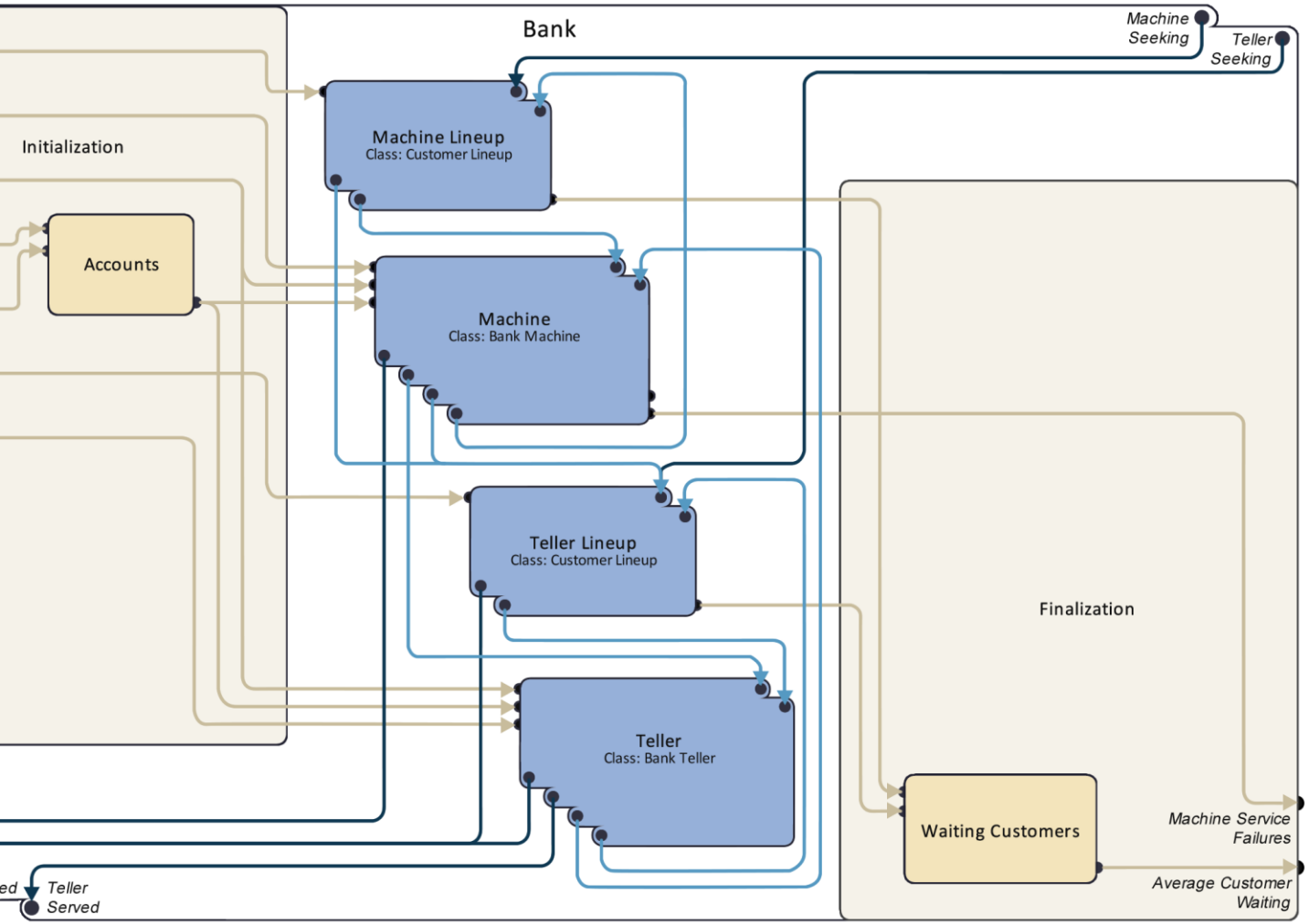

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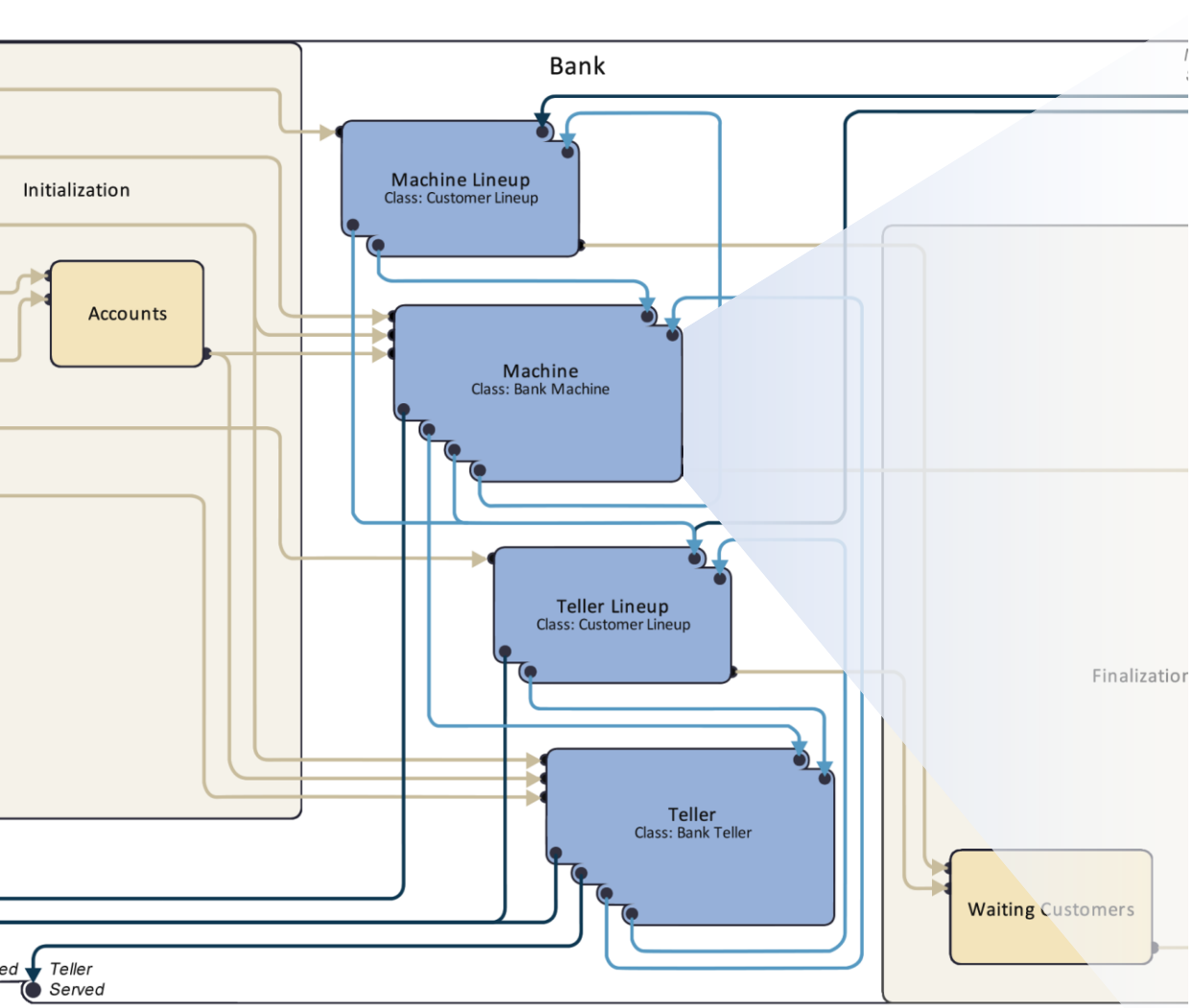

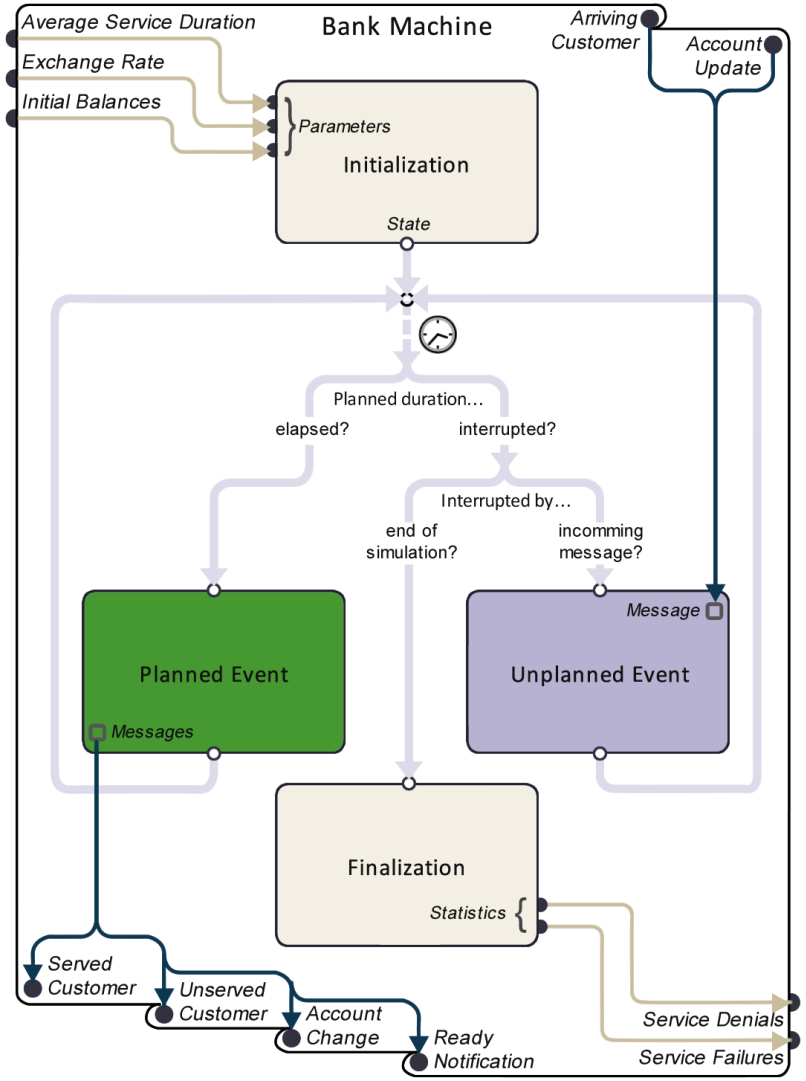

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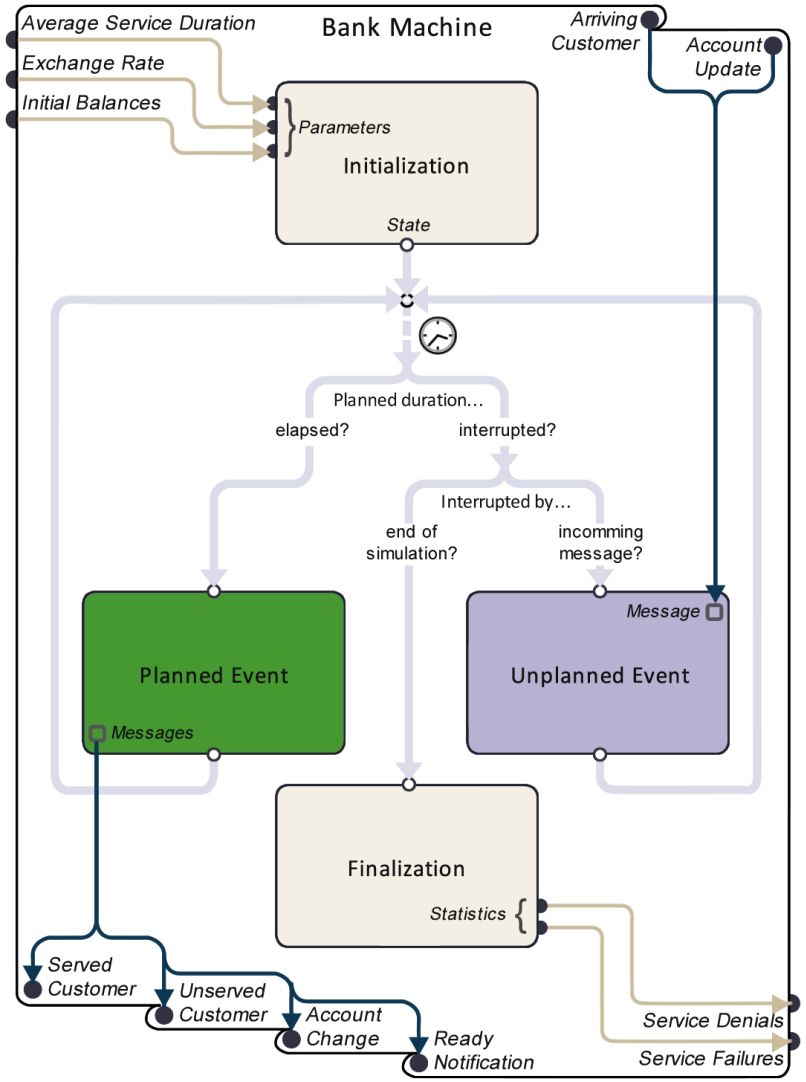

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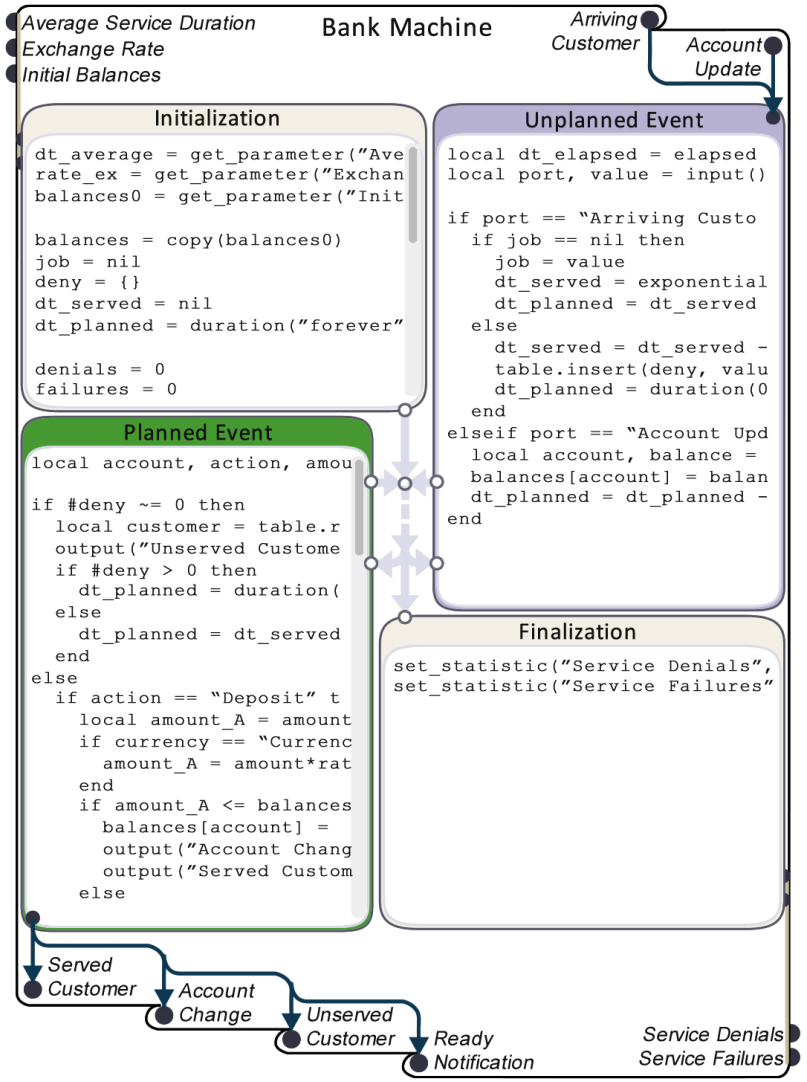
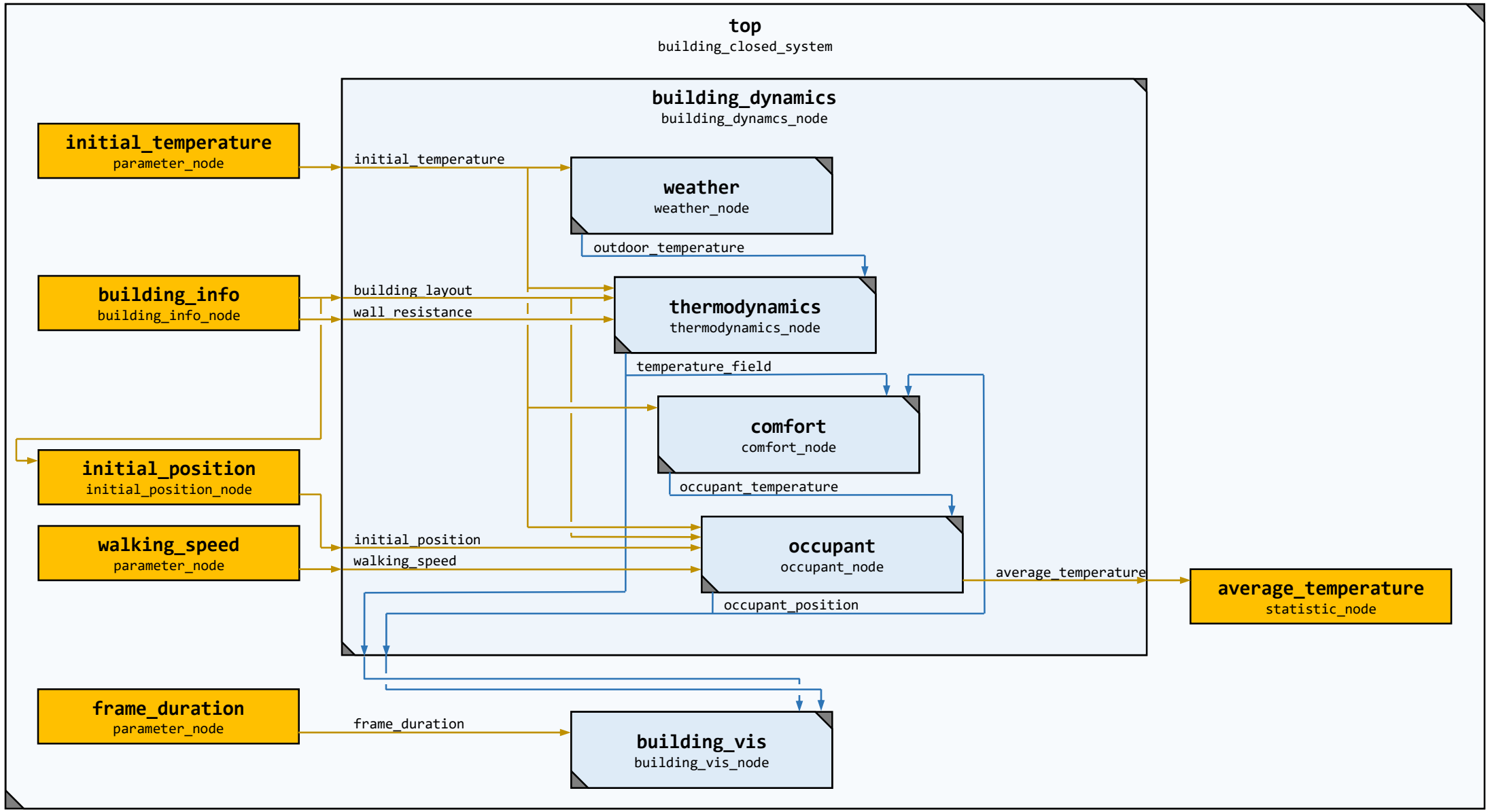


Example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initial_temperature
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weather_node
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building_layout
wall_resistance
thermodynamics
thermodynamics_node
temperature_field
comfort
comfort_node
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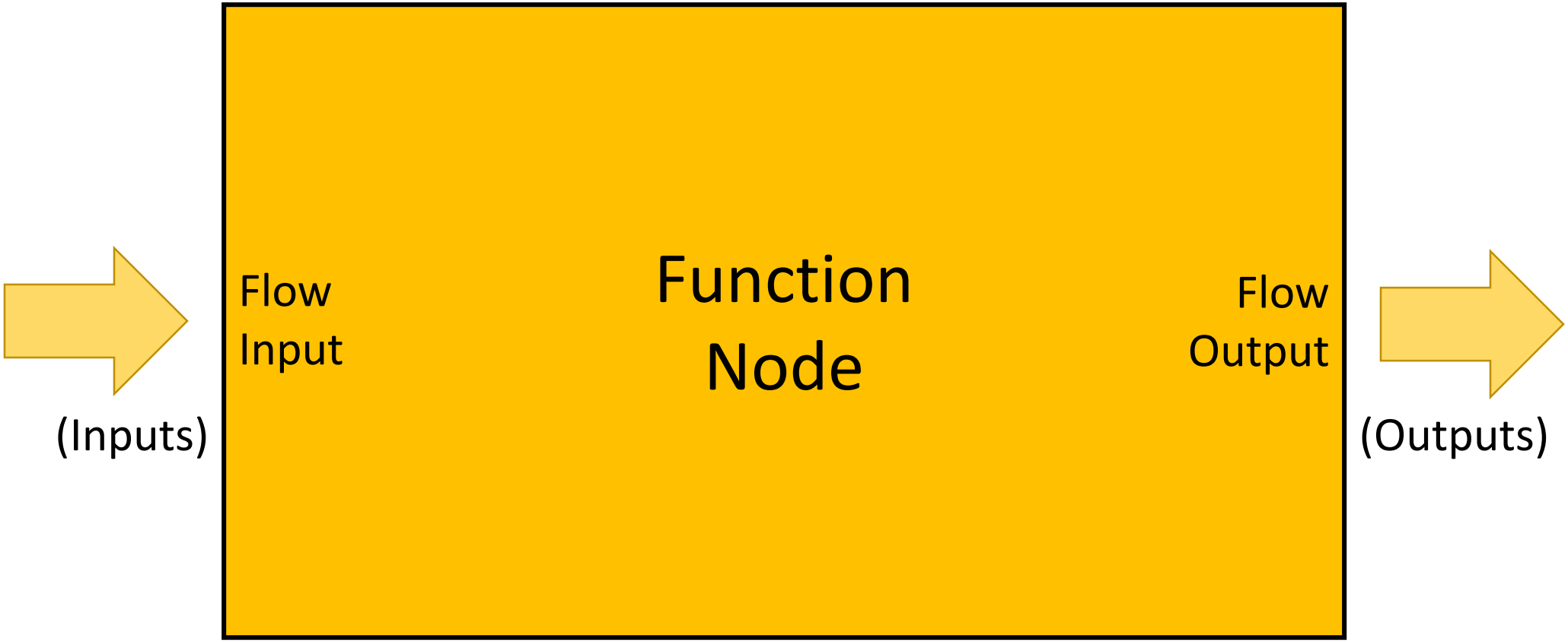
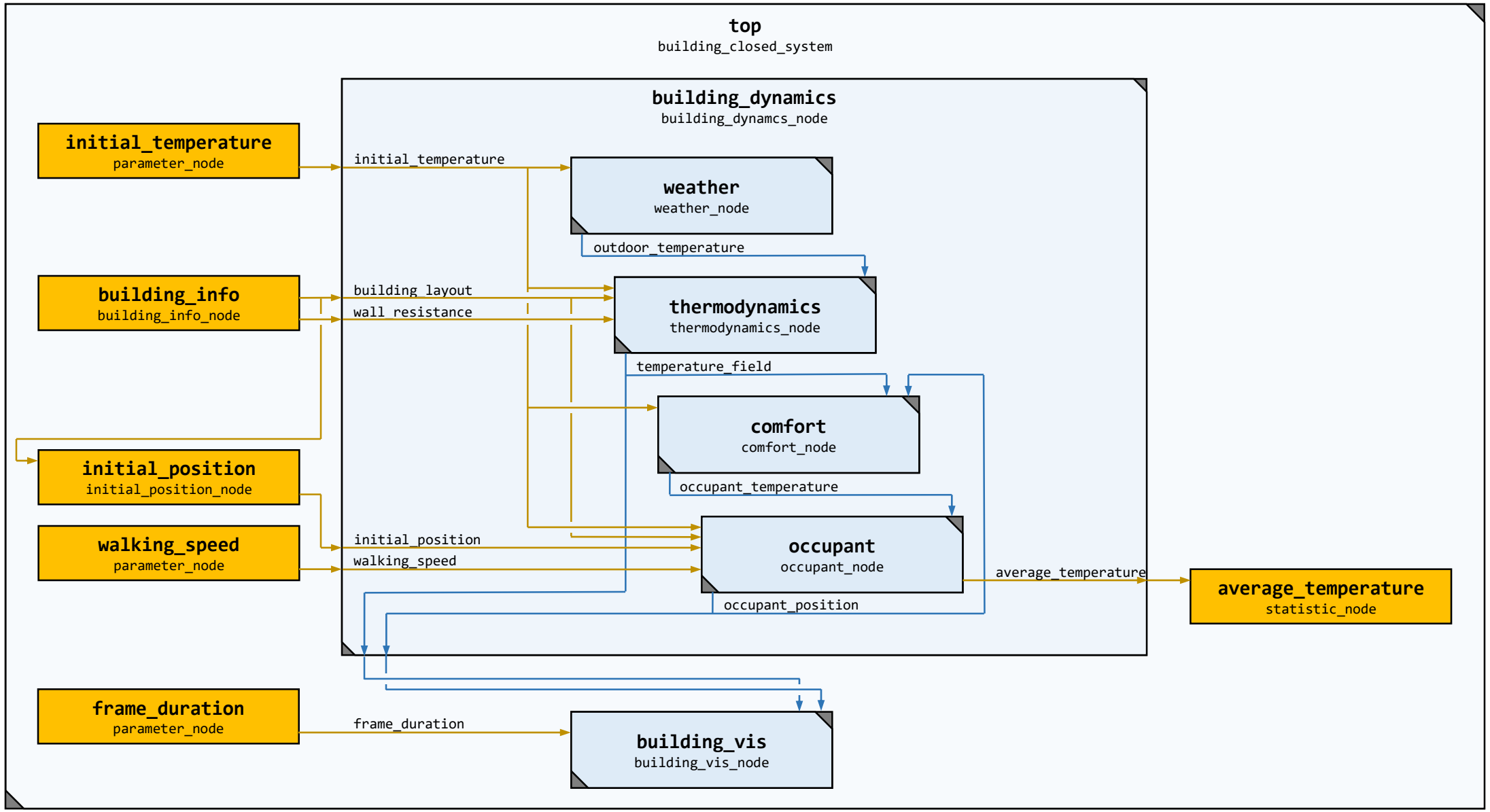
initial_position_node
occupant_temperature
walking_speed
parameter_node
initial_position
walking_speed
occupant
occupant_node
average_temperature
average_temperature
statistic_node
occupant_position
frame_duration
parameter_node
frame_duration
building_vis
building_vis_node

Example – Function Nodes

Example – Function Nodes



Example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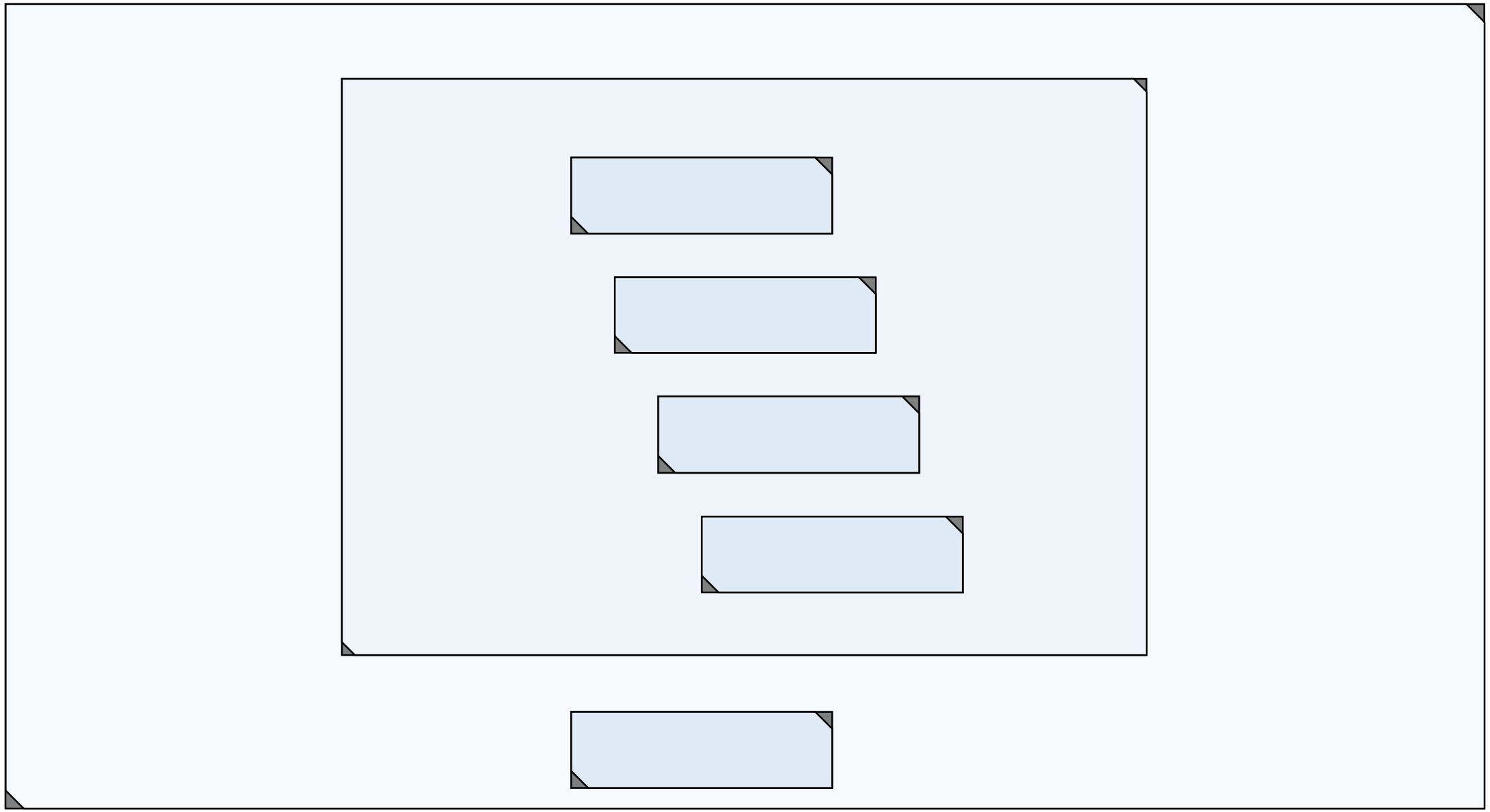
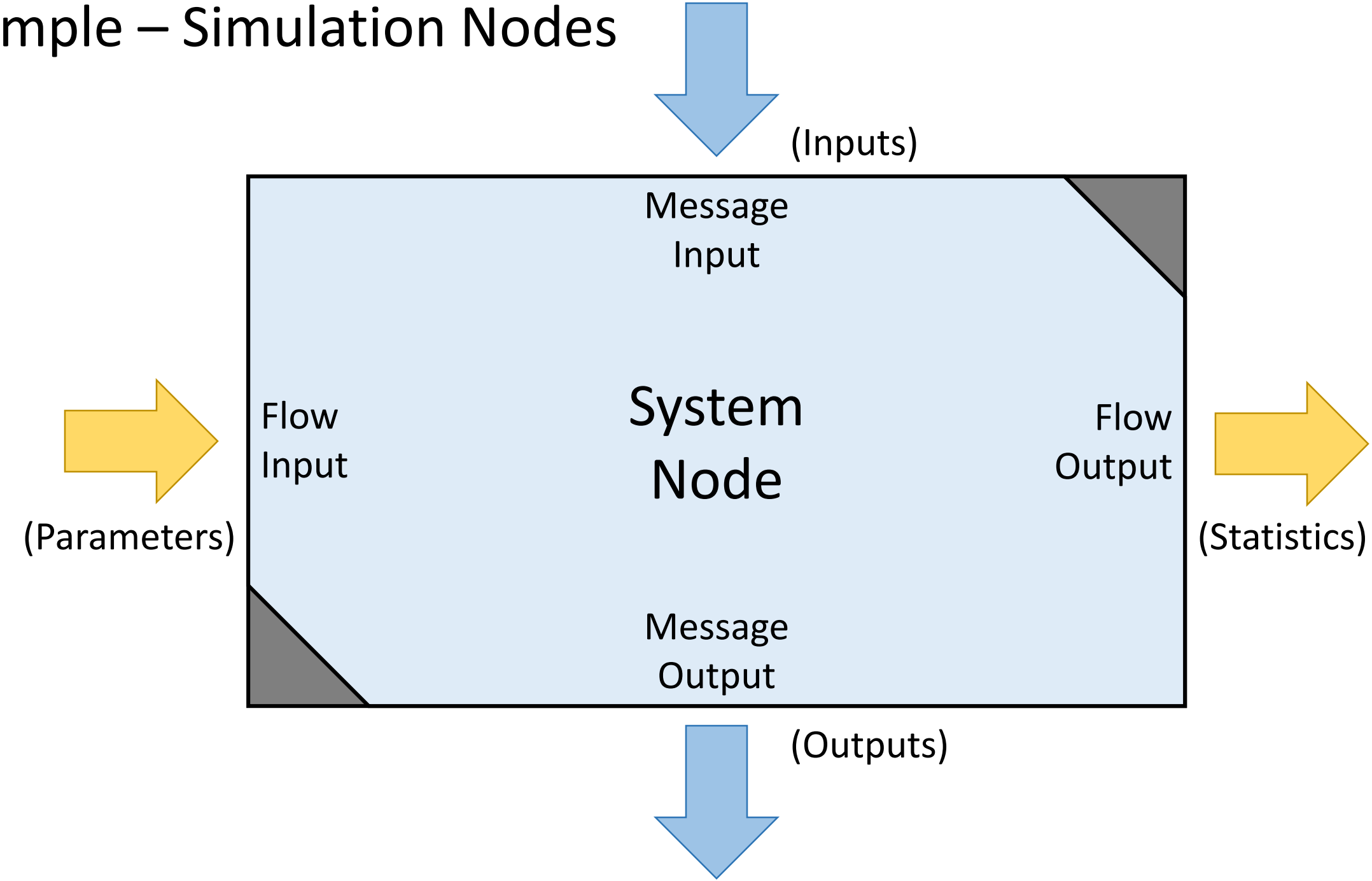
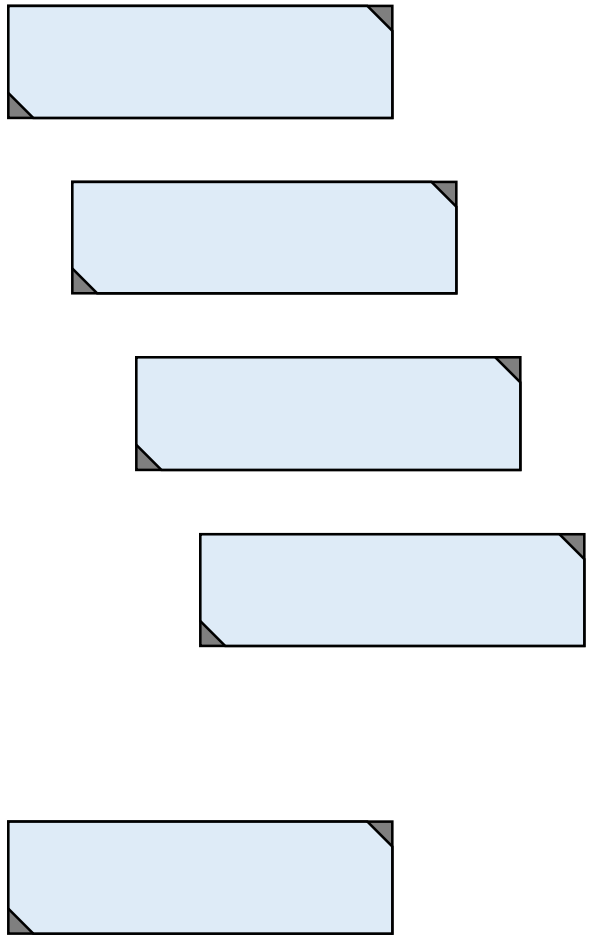
Example – Simulation Nodes



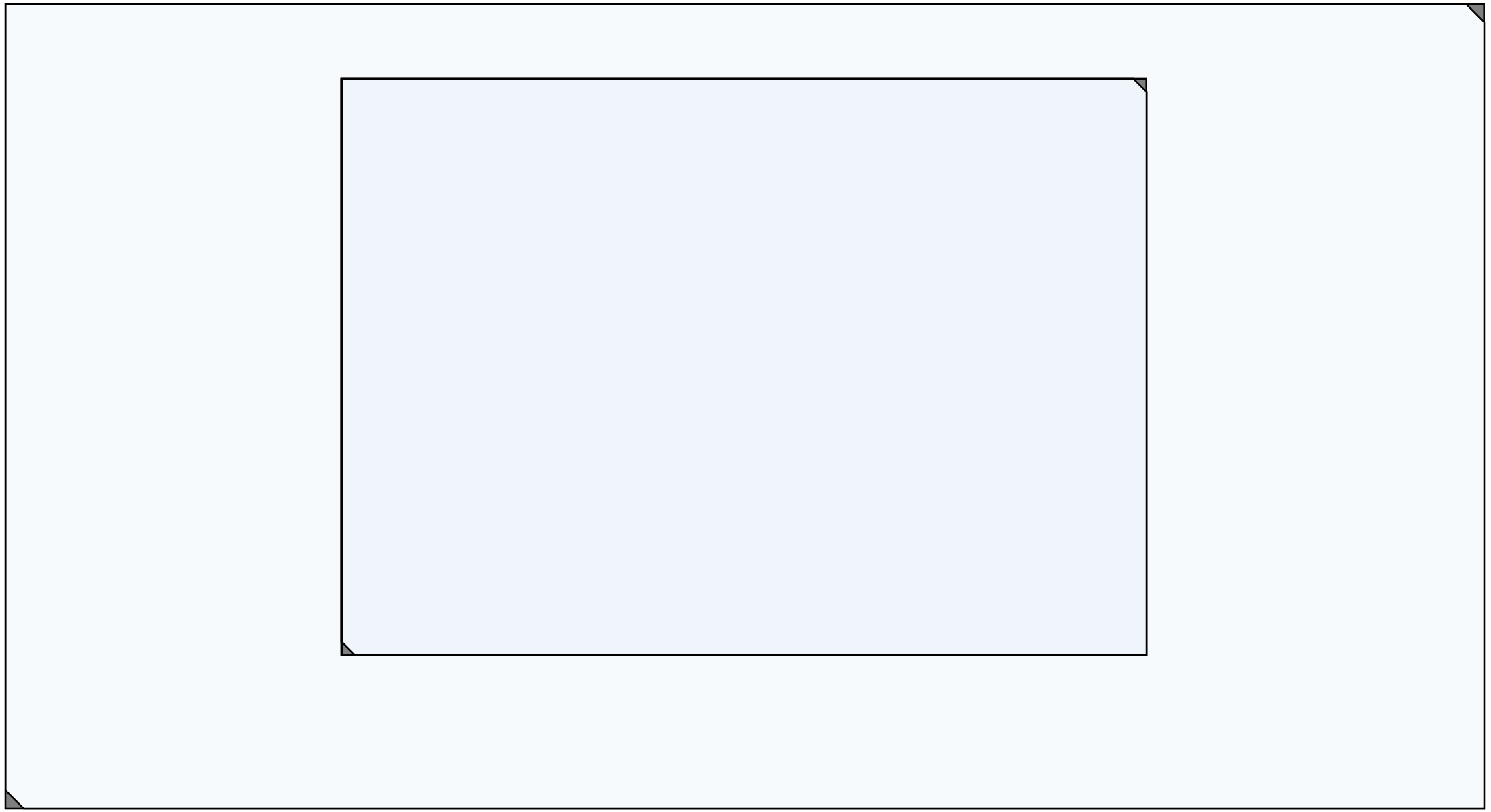
Example – Simulation Nodes



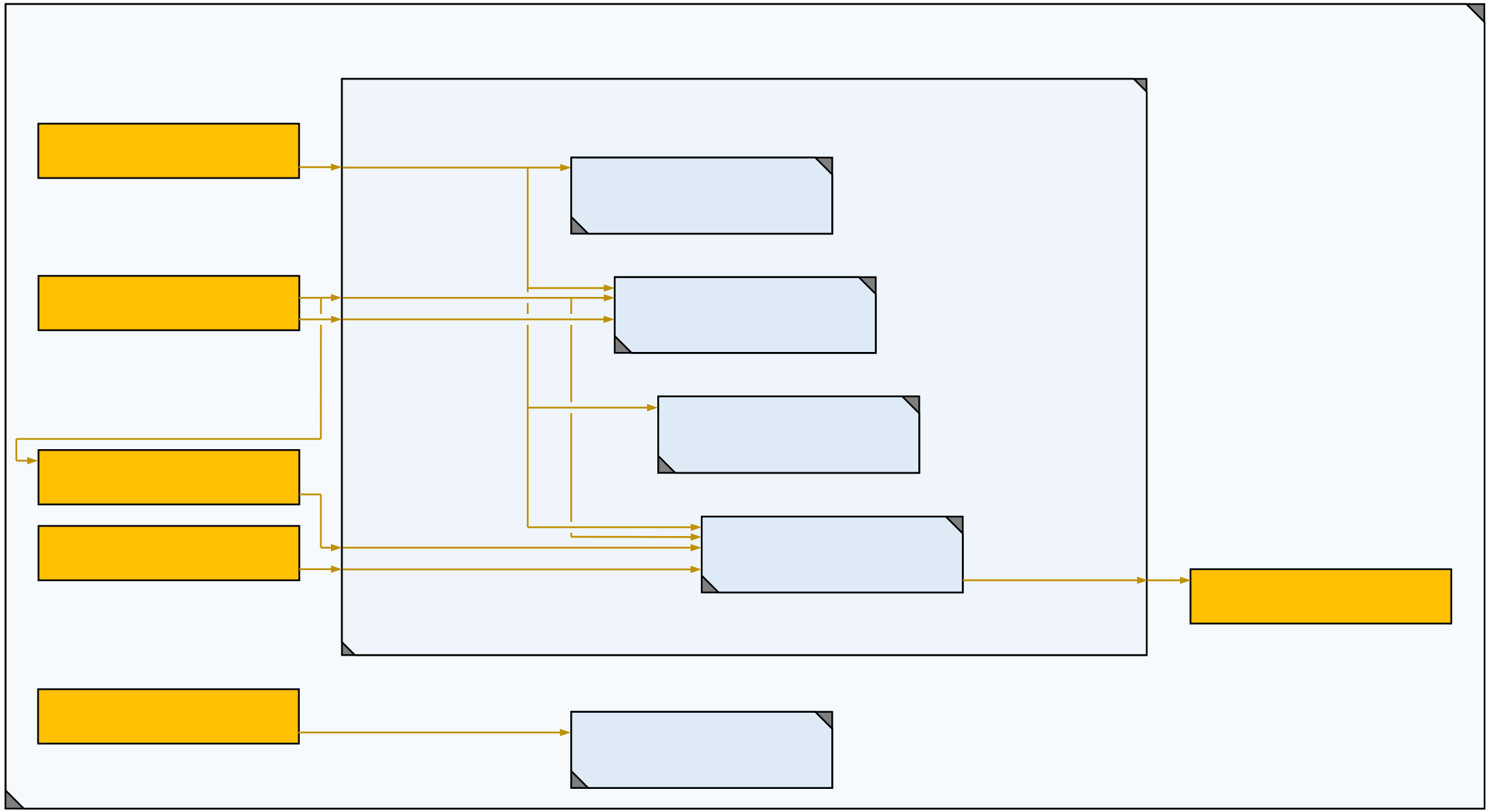
Example – Atomic Nodes



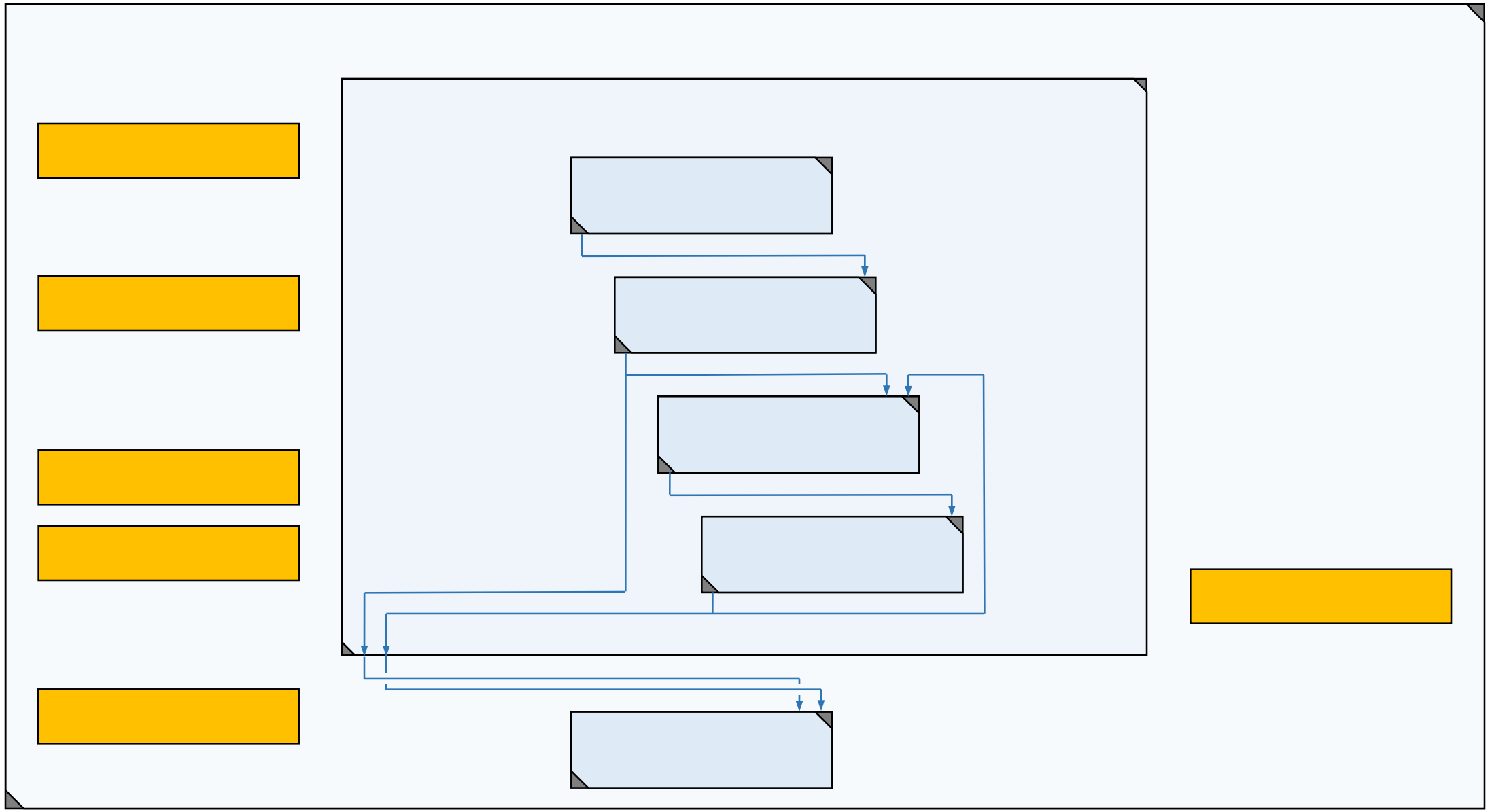
Example – Composite Nodes



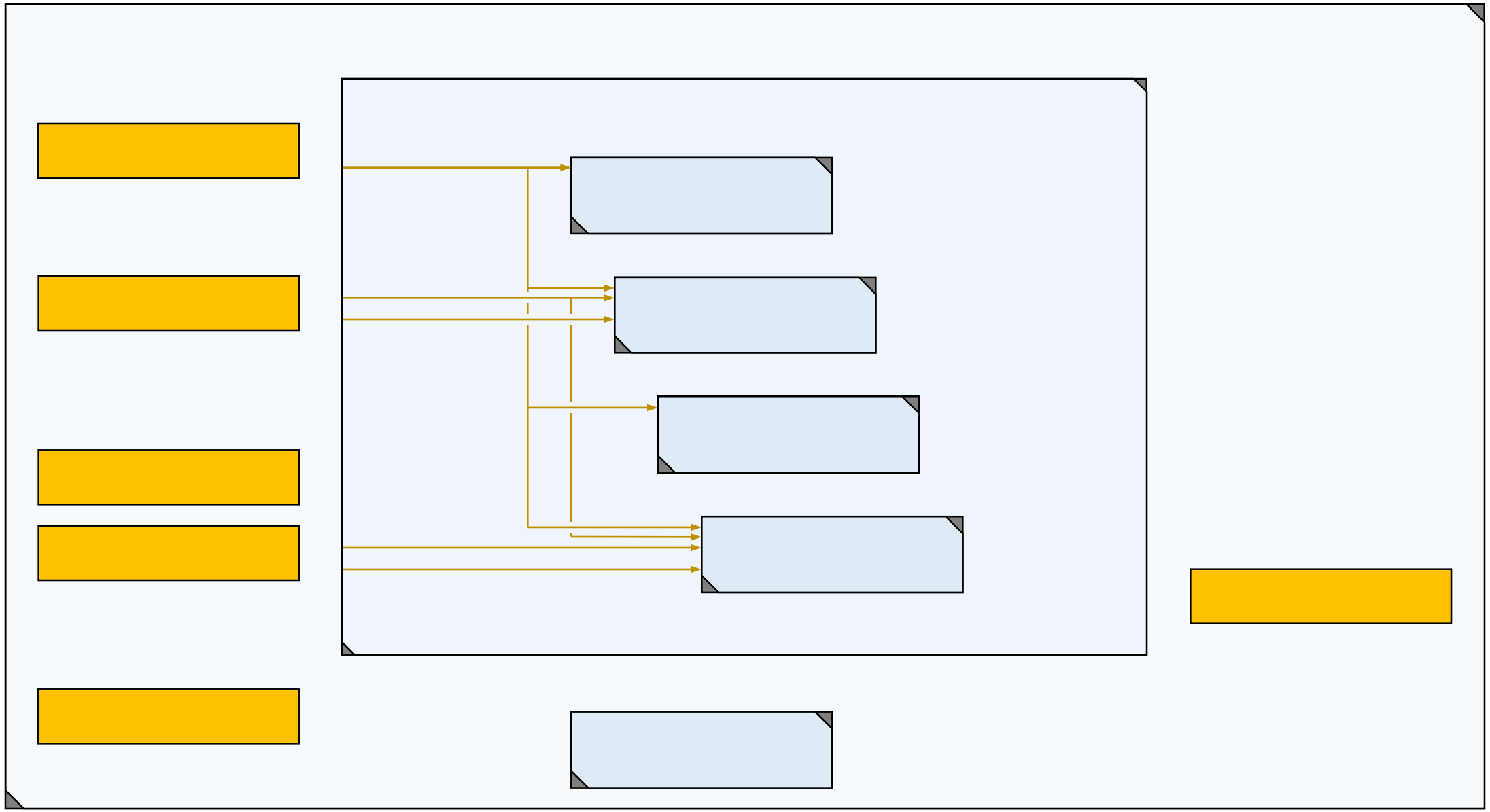
Example – Flow Links



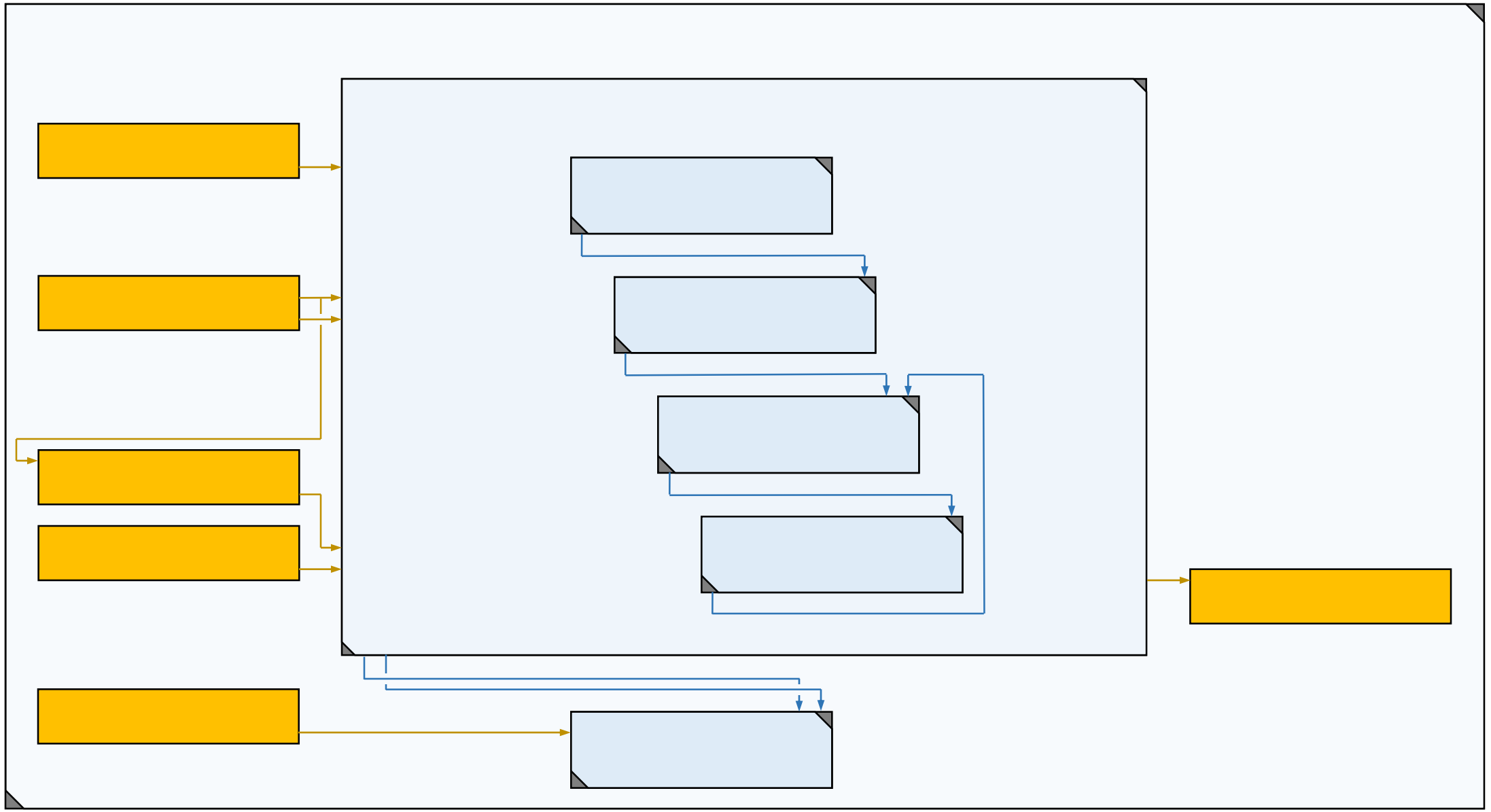
Example – Message Links



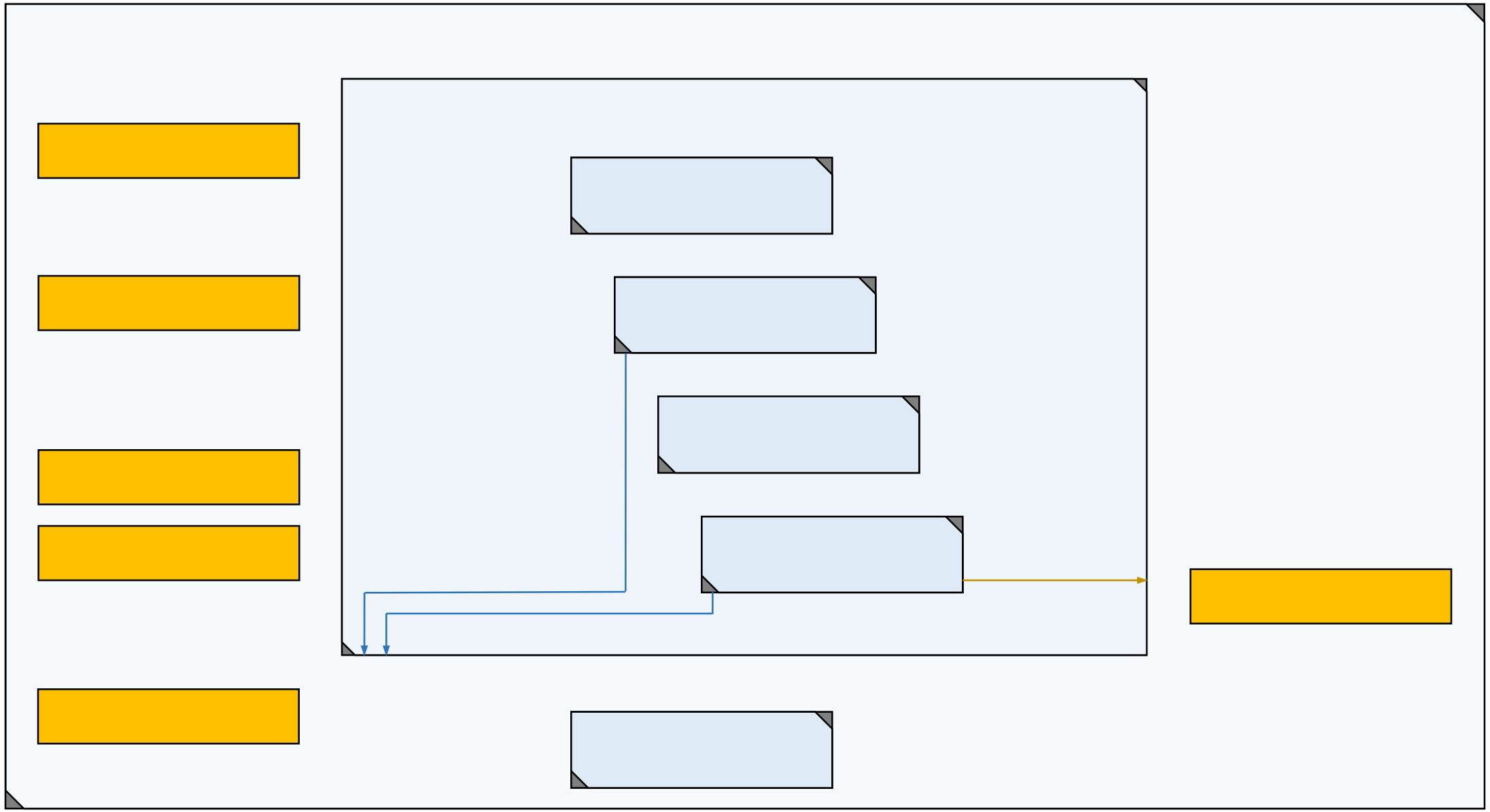
Example – Inward Links



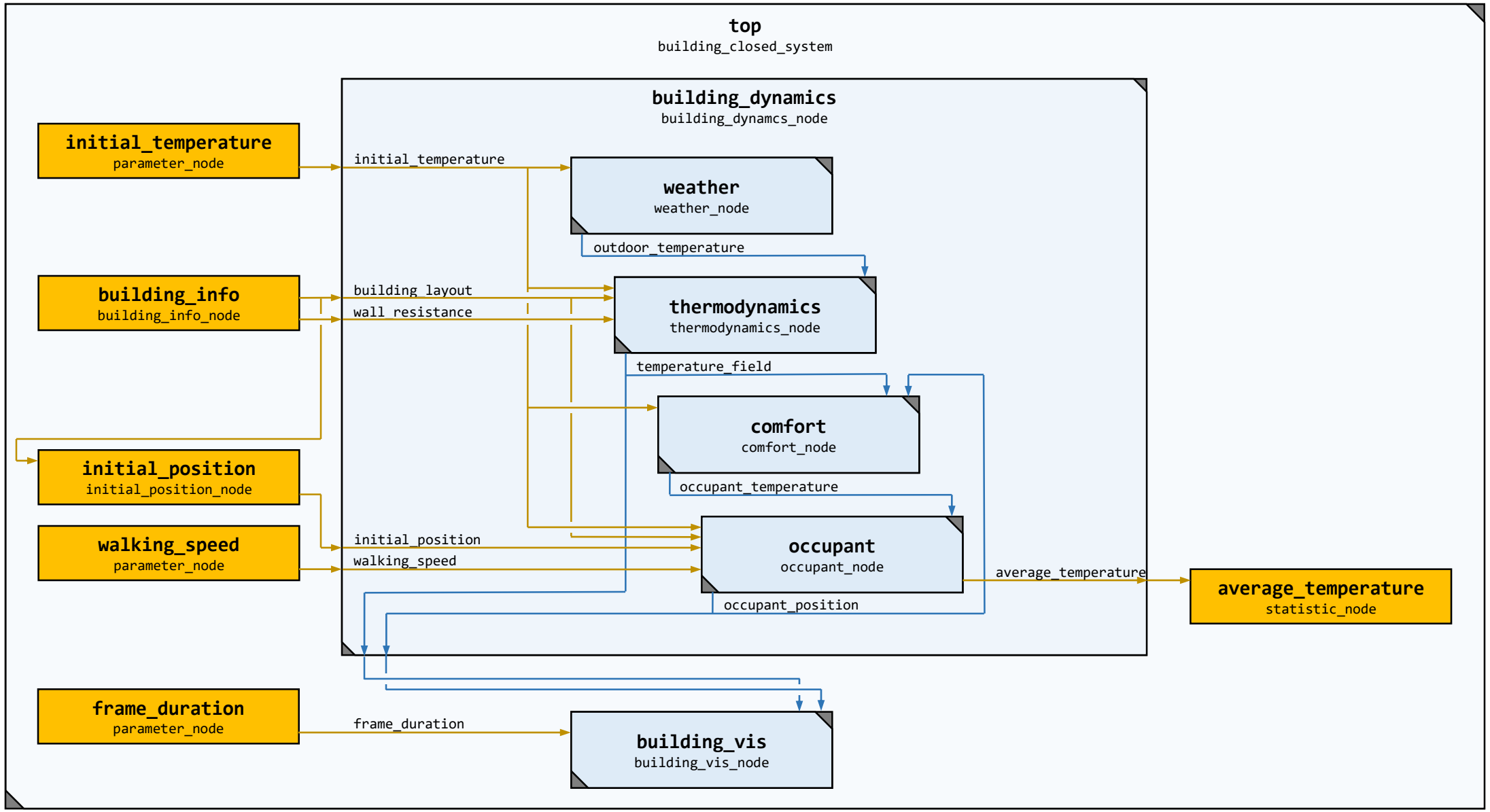
Example – Inner Links



Example – Outward Links



Example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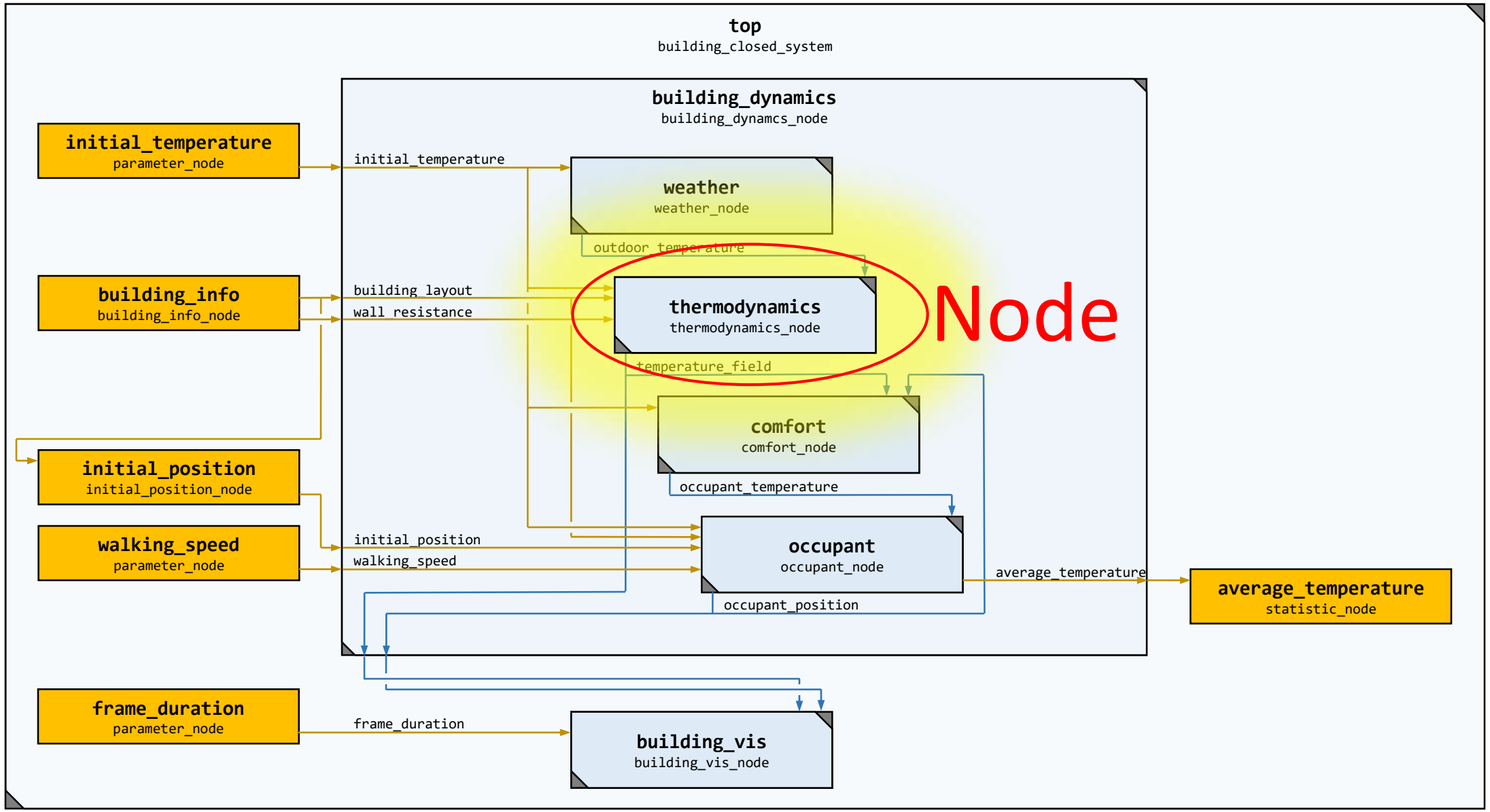
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Example

Node

```
class thermodynamics_node : public atomic_node
{
public:
    port<flow, input, thermodynamic_temperature> initial_temperature_input;
    port<flow, input, std::pair<array2d<int64>, distance>> building_layout_input;
    port<flow, input, float64> wall_resistance_input;
    port<message, input, thermodynamic_temperature> outdoor_temperature_input;
    port<message, output, array2d<thermodynamic_temperature>> temperature_field_output;

protected:
    array2d<int64> L;                          // building layout
    int64 nx;                                  // number of cells in the x dimension
    int64 ny;                                  // number of cells in the y dimension
    float64 wall_R;                            // wall resistance
    array2d<thermodynamic_temperature> TF;     // temperature field
    duration step_dt;                          // time step
    duration planned_dt;                       // planned duration

    virtual duration initialization_event();
    virtual duration unplanned_event(duration elapsed_dt);
    virtual duration planned_event(duration elapsed_dt);
    virtual void finalization_event(duration elapsed_dt);
};
```

Example

Types of Nodes

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```

Example

Types of Nodes

```
class system_node
{
};

class atomic_node: public system_node
{
    virtual duration initialization_event() = 0;
    virtual duration unplanned_event(duration elapsed_dt) = 0;
    virtual duration planned_event(duration elapsed_dt) = 0;
    virtual void finalization_event(duration elapsed_dt) = 0;
};

class composite_node : public system_node
{
    void inward_link(port<dmode, input, T>& src_port, port<dmode, input, T>& dst_port);
    void inner_link(port<dmode, output, T>& src_port, port<dmode, input, T>& dst_port);
    void outward_link(port<dmode, output, T>& src_port, port<dmode, output, T>& dst_port);
}

class function_node : public system_node
{
    virtual void flow_event() = 0;
};
```

```
// Also...
class collection_node ...
```

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Event Handlers

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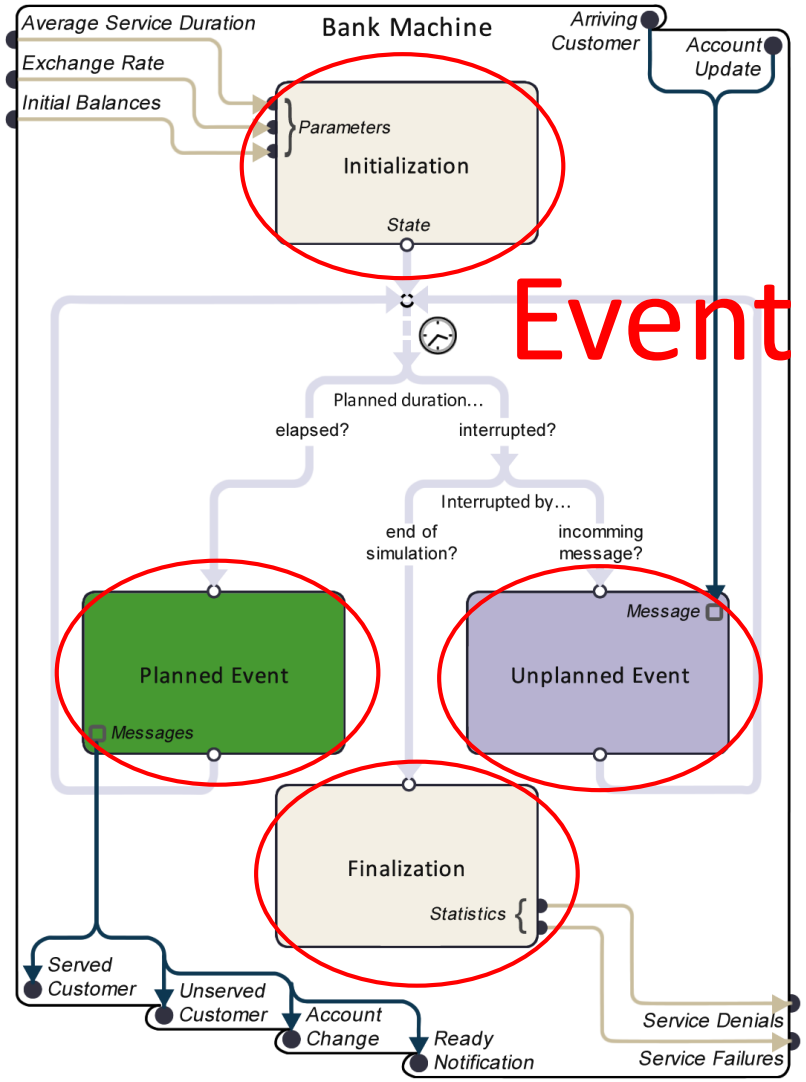
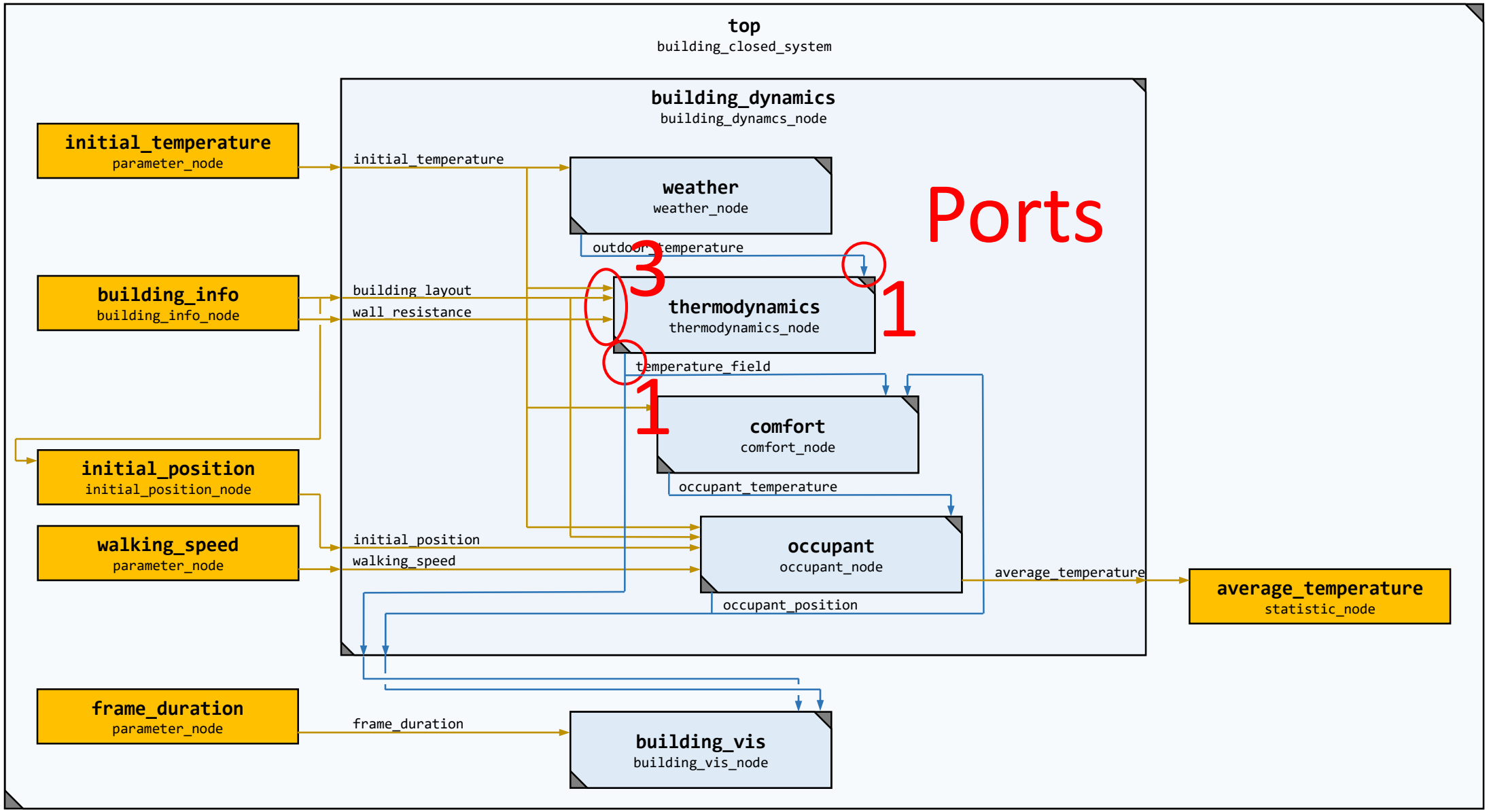


Event Handlers

Example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Ports
3
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    array2d<int64> L;                          // building layout
    int64 nx;                                  // number of cells in the x dimension
    int64 ny;                                  // number of cells in the y dimension
    float64 wall_R;                            // wall resistance
    array2d<thermodynamic_temperature> TF;     // temperature field
    duration step_dt;                          // time step
    duration planned_dt;                       // planned duration

    virtual duration initialization_event();
    virtual duration unplanned_event(duration elapsed_dt);
    virtual duration planned_event(duration elapsed_dt);
    virtual void finalization_event(duration elapsed_dt);
};
```

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Example

Example

Data types

```
class thermodynamics_node : public atomic_node
{
public:
    port<flow, input, thermodynamic_temperature> initial_temperature_input;
    port<flow, input, std::pair<array2d<int64>, distance>> building_layout_input;
    port<flow, input, float64> wall_resistance_input;
    port<message, input, thermodynamic_temperature> outdoor_temperature_input;
    port<message, output, array2d<thermodynamic_temperature>> temperature_field_output;

protected:
    array2d<int64> L;                          // building layout
    int64 nx;                                  // number of cells in the x dimension
    int64 ny;                                  // number of cells in the y dimension
    float64 wall_R;                            // wall resistance
    array2d<thermodynamic_temperature> TF;     // temperature field
    duration step_dt;                          // time step
    duration planned_dt;                       // planned duration

    virtual duration initialization_event();
    virtual duration unplanned_event(duration elapsed_dt);
    virtual duration planned_event(duration elapsed_dt);
    virtual void finalization_event(duration elapsed_dt);
};
```

Example

Data types

```
// Core Types

pointer  // not sortable; encapsulates std::shared_ptr<void>

bool          // sortable
int64         // sortable
float64       // sortable
std::string   // sortable
quantity<U>   // sortable; includes e.g. distance, duration, quantity<decltype(_kg*_m/_s/_s)>

arraynd<T, ndims>      // valid if T is valid; not sortable
std::pair<T1, T2>      // valid if T1, T2 are valid; sortable if T1, T2 are sortable
std::tuple<T>          // valid if T is valid; sortable if T is sortable
std::tuple<T, Ts...>   // valid if T, Ts... are valid; sortable if T, Ts... are sortable
std::vector<T>         // valid if T is valid; sortable if T is sortable
std::set<T>            // valid if T is valid; sortable if T is sortable
std::map<Key, T>       // valid if T is valid and Key is valid and sortable;
                       //     sortable if T is sortable
std::shared_ptr<T>     // not sortable

T default_value<T>()   // create a default value of core type T
tostring(const T&)     // convert the value of core type T to a string
```

```cpp
#include <my_cpp_libraries/my_CFD_solver.h>

class CFD_node : public atomic_node
{
public:
    port<message, output, array3d<float>> velocities;

protected:
    my_CFD_solver_state CFD_state;

    virtual duration initialization_event()
    {
        CFD_state = initialize_my_CFD_solver();
        return 5_s;  // planned_dt
    }

    virtual duration planned_event(duration elapsed_dt)
    {
        advance_one_time_step_using_my_CFD_solver(CFD_state);
        velocities.send(CFD_state.get_velocities);
        return 5_s;  // planned_dt
    }
};
```

2nd Example

```
#include <my_cpp_libraries/my_CFD_solver.h>

class CFD_node : public atomic_node
{
public:
    port<message, output, array3d<float>> velocities;

protected:
    my_CFD_solver_state CFD_state;

    virtual duration initialization_event()
    {
        CFD_state = initialize_my_CFD_solver();
        return 5_s;  // planned_dt
    }

    virtual duration planned_event(duration elapsed_dt)
    {
        advance_one_time_step_using_my_CFD_solver(CFD_state);
        velocities.send(CFD_state.get_velocities);
        return 5_s;  // planned_dt
    }
};
```

Possible to wrap existing simulation libraries (eg. CFD)

2nd Example

```
#include <my_cpp_libraries/my_CFD_solver.h>

class CFD_node : public atomic_node
{
public:
    port<message, output, array3d<float>> velocities;

protected:
    my_CFD_solver_state CFD_state;

    virtual duration initialization_event()
    {
        CFD_state = initialize_my_CFD_solver();
        return 5_s;  // planned_dt
    }

    virtual duration planned_event(duration elapsed_dt)
    {
        advance_one_time_step_using_my_CFD_solver(CFD_state);
        velocities.send(CFD_state.get_velocities);
        return 5_s;  // planned_dt
    }
};
```

The library includes multidimensional arrays

2nd Example

```
#include <my_cpp_libraries/my_CFD_solver.h>

class CFD_node : public atomic_node
{
public:
    port<message, output, array3d<float>> velocities;

protected:
    my_CFD_solver_state CFD_state;

    virtual duration initialization_event()
    {
        CFD_state = initialize_my_CFD_solver();
        return 5_s;  // planned_dt
    }

    virtual duration planned_event(duration elapsed_dt)
    {
        advance_one_time_step_using_my_CFD_solver(CFD_state);
        velocities.send(CFD_state.get_velocities);
        return 5_s;  // planned_dt
    }
};
```

Elapsed durations and planned durations are important concepts

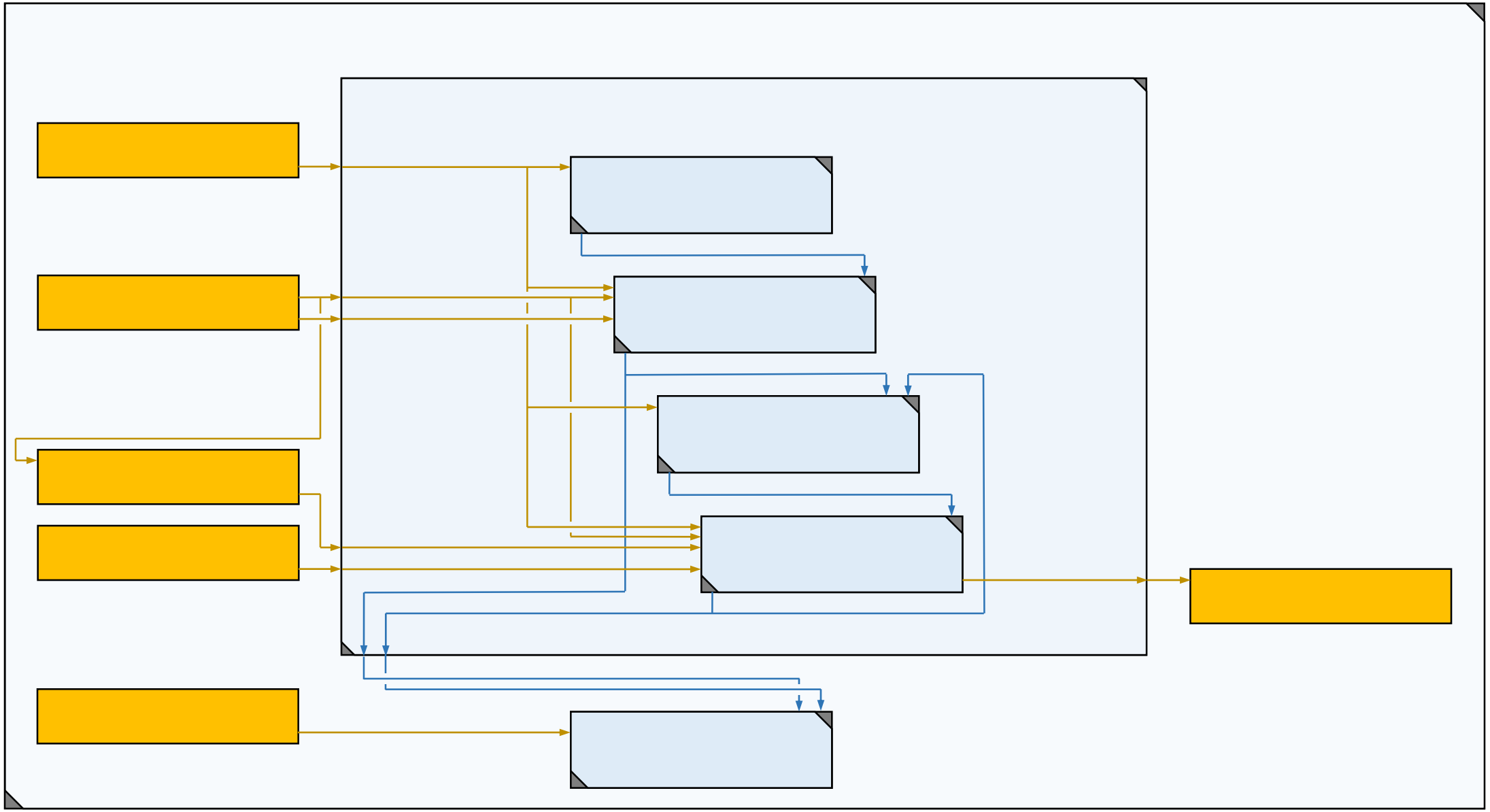
2nd Example

```cpp
#include <my_cpp_libraries/my_CFD_solver.h>

class CFD_node : public atomic_node
{
public:
    port<message, output, array3d<float>> velocities;

protected:
    my_CFD_solver_state CFD_state;

    virtual duration initialization_event()
    {
        CFD_state = initialize_my_CFD_solver();
        return 5_s;  // planned_dt
    }

    virtual duration planned_event(duration elapsed_dt)
    {
        advance_one_time_step_using_my_CFD_solver(CFD_state);
        velocities.send(CFD_state.get_velocities);
        return 5_s;  // planned_dt
    }
};
```

SI units are represented explicitly and checked at compile-time

2nd Example

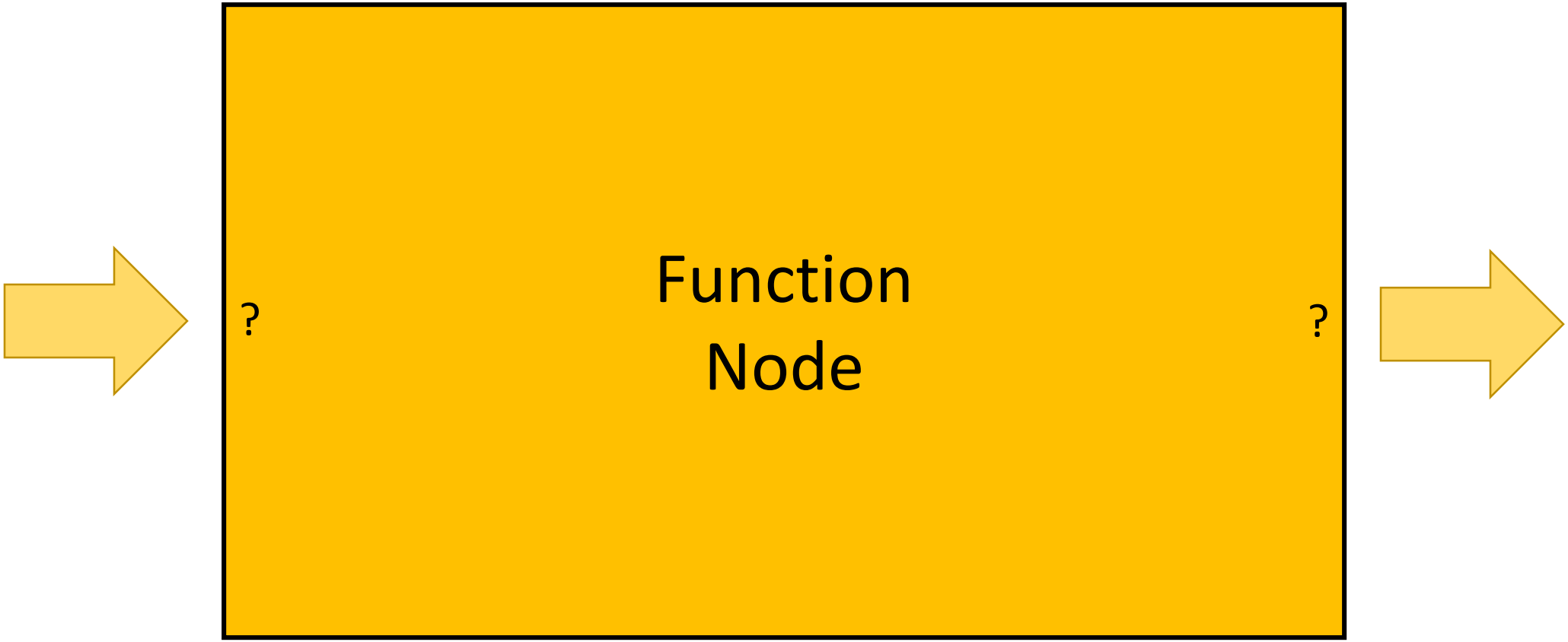
Review



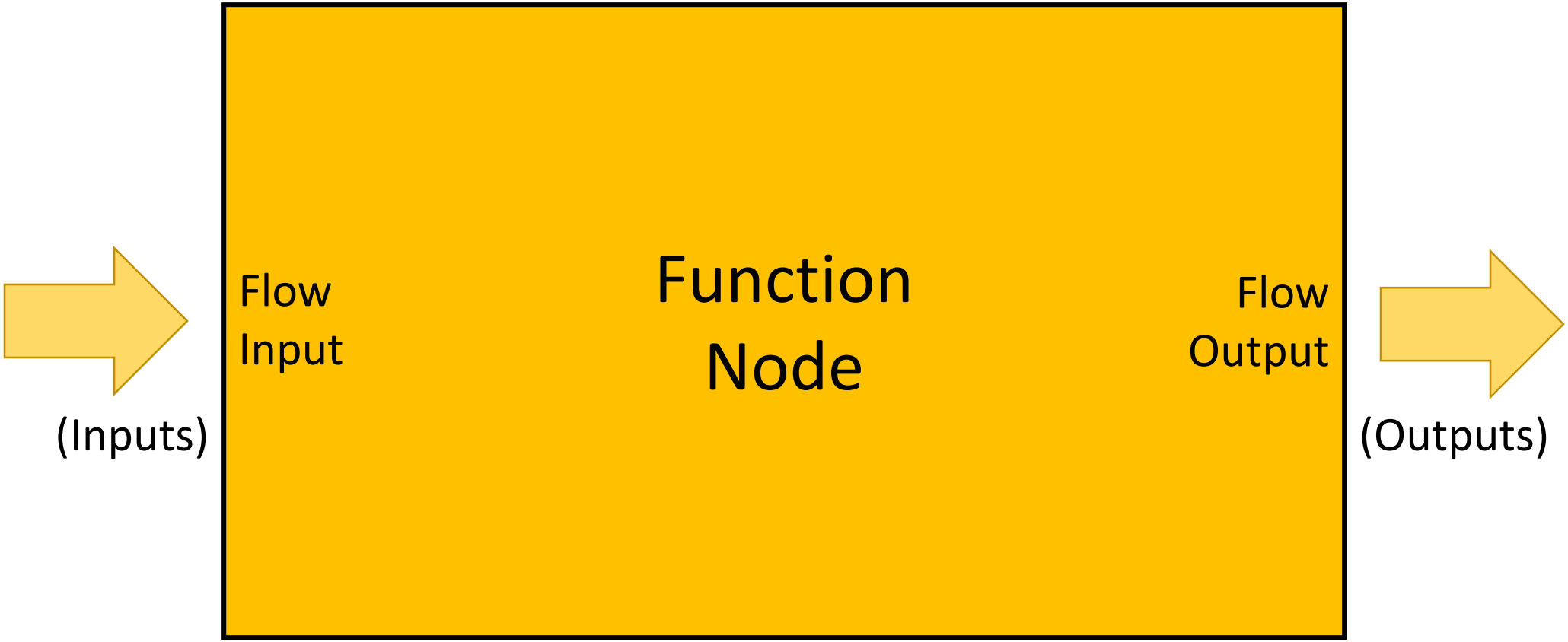
Review – ?

Review – Function Nodes

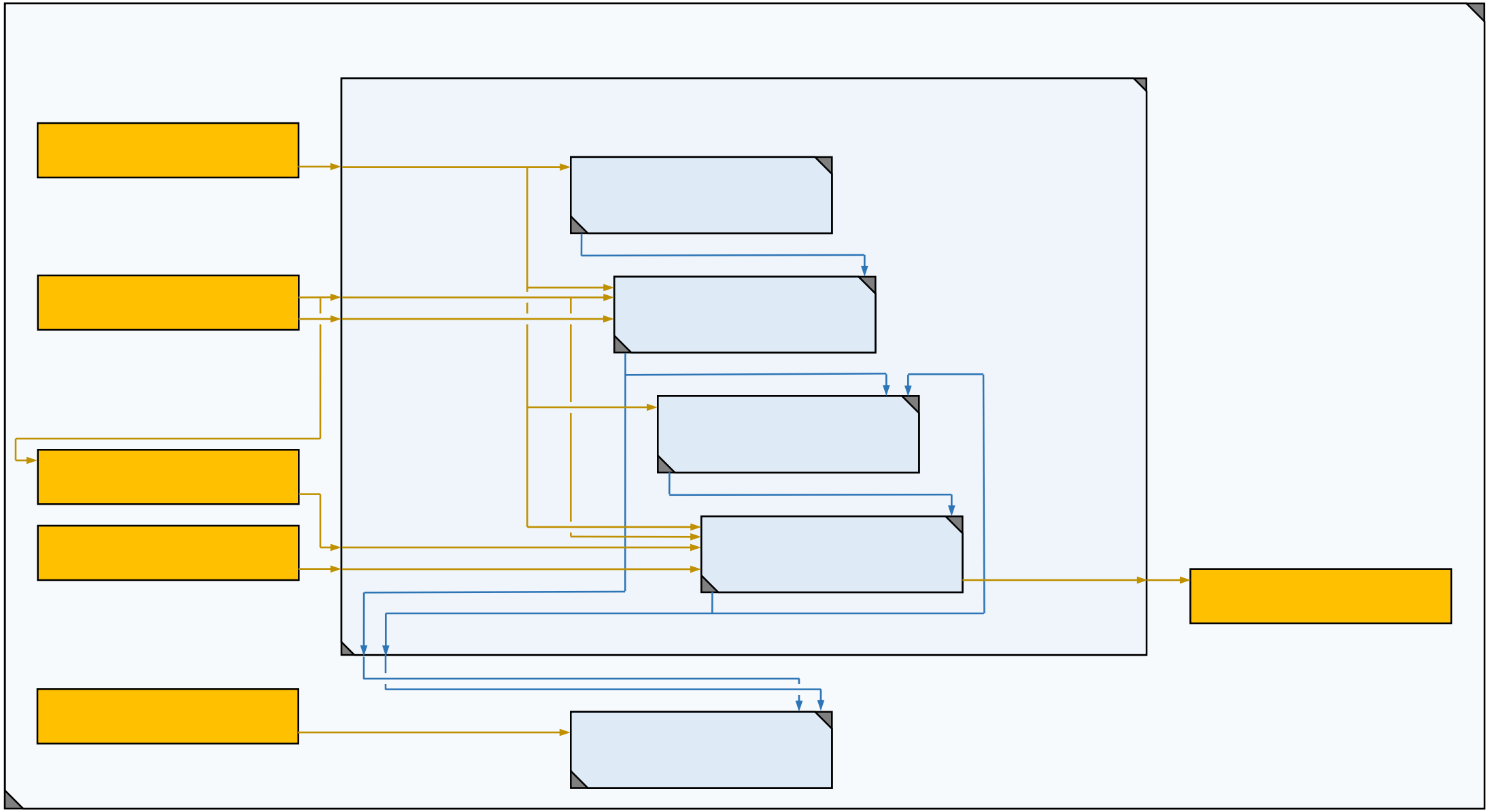
Review – Function Nodes



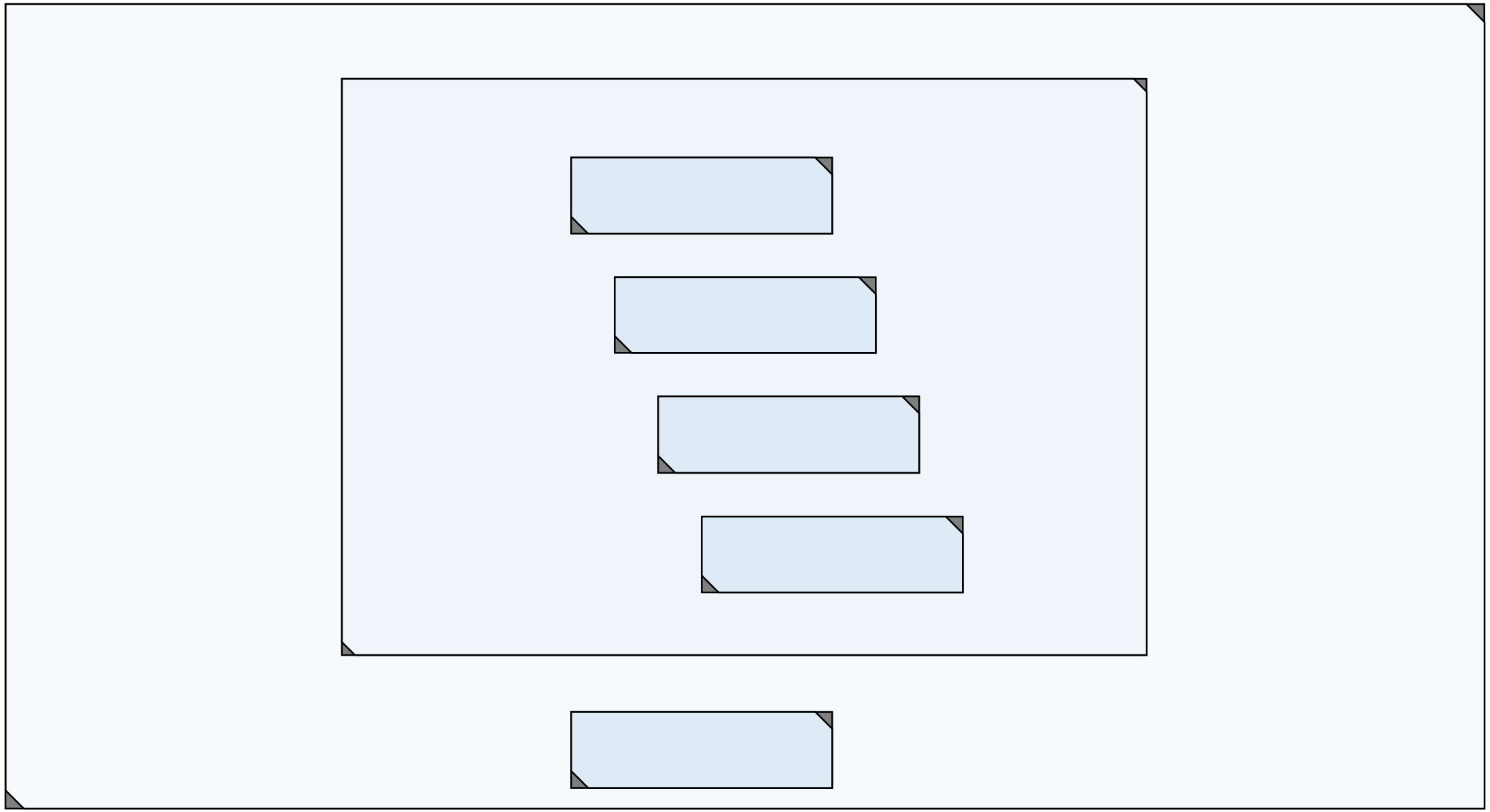
Review – Function Nodes



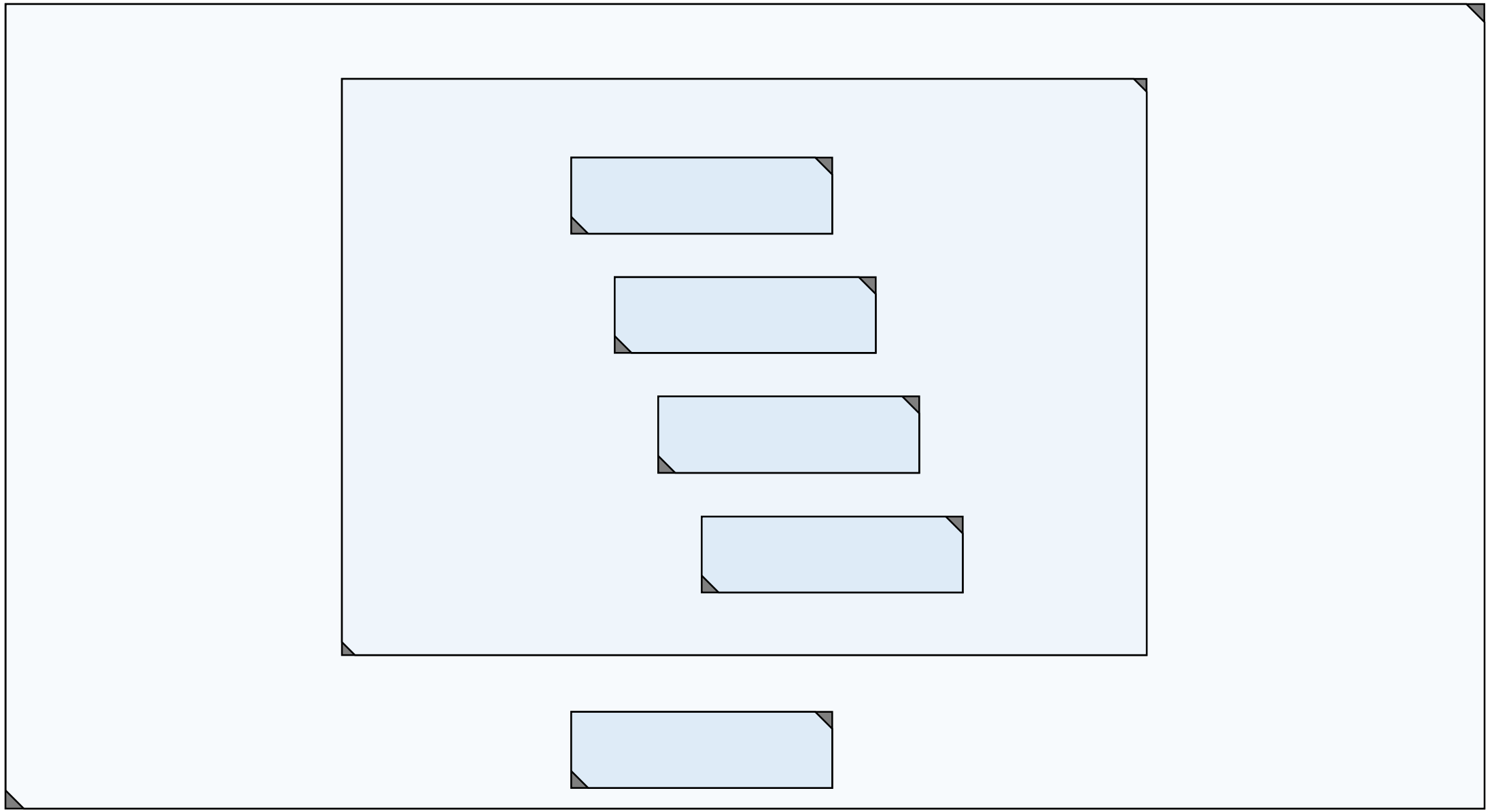
Review



Review – ?



Review – Simulation Nodes



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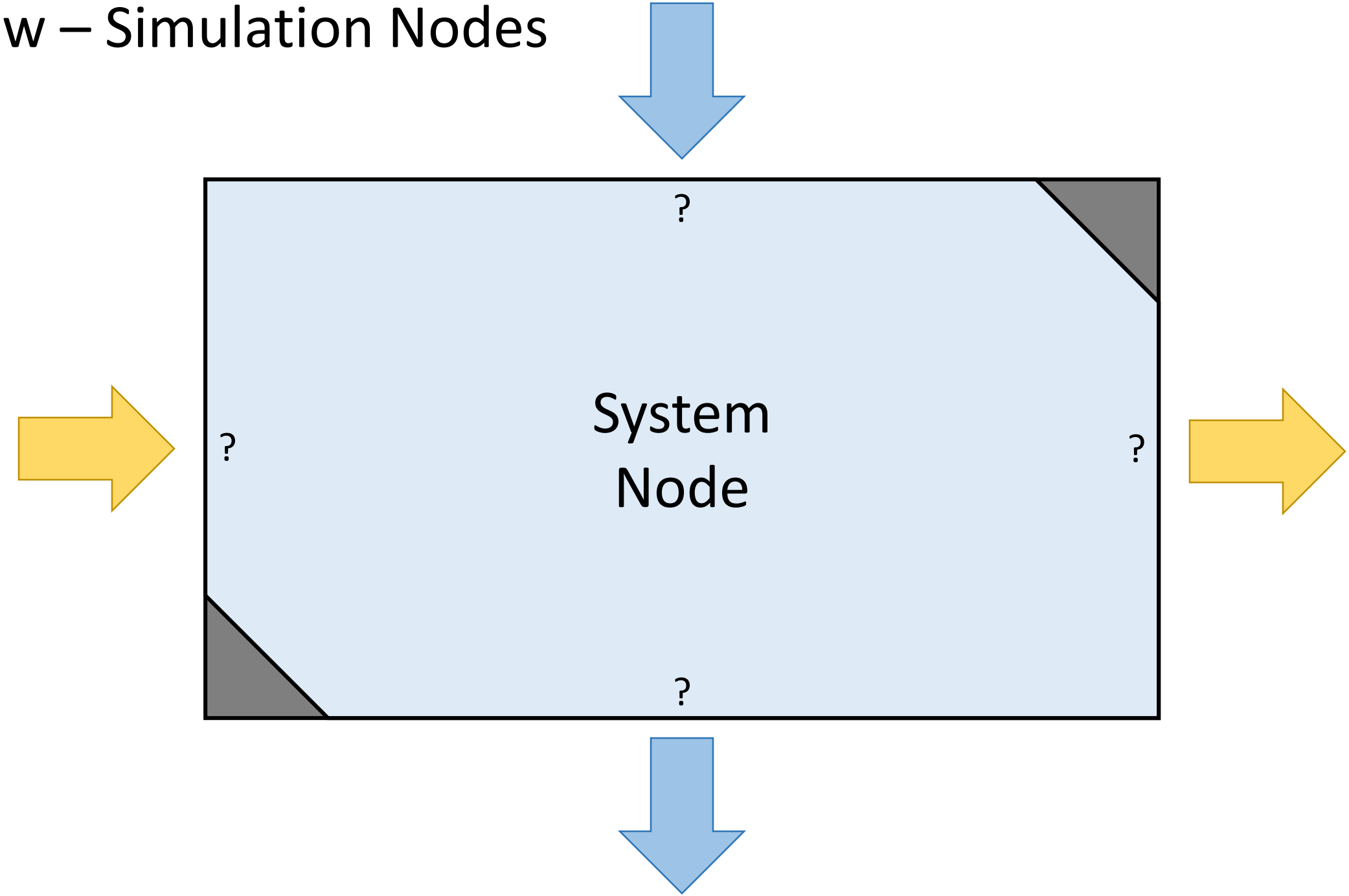

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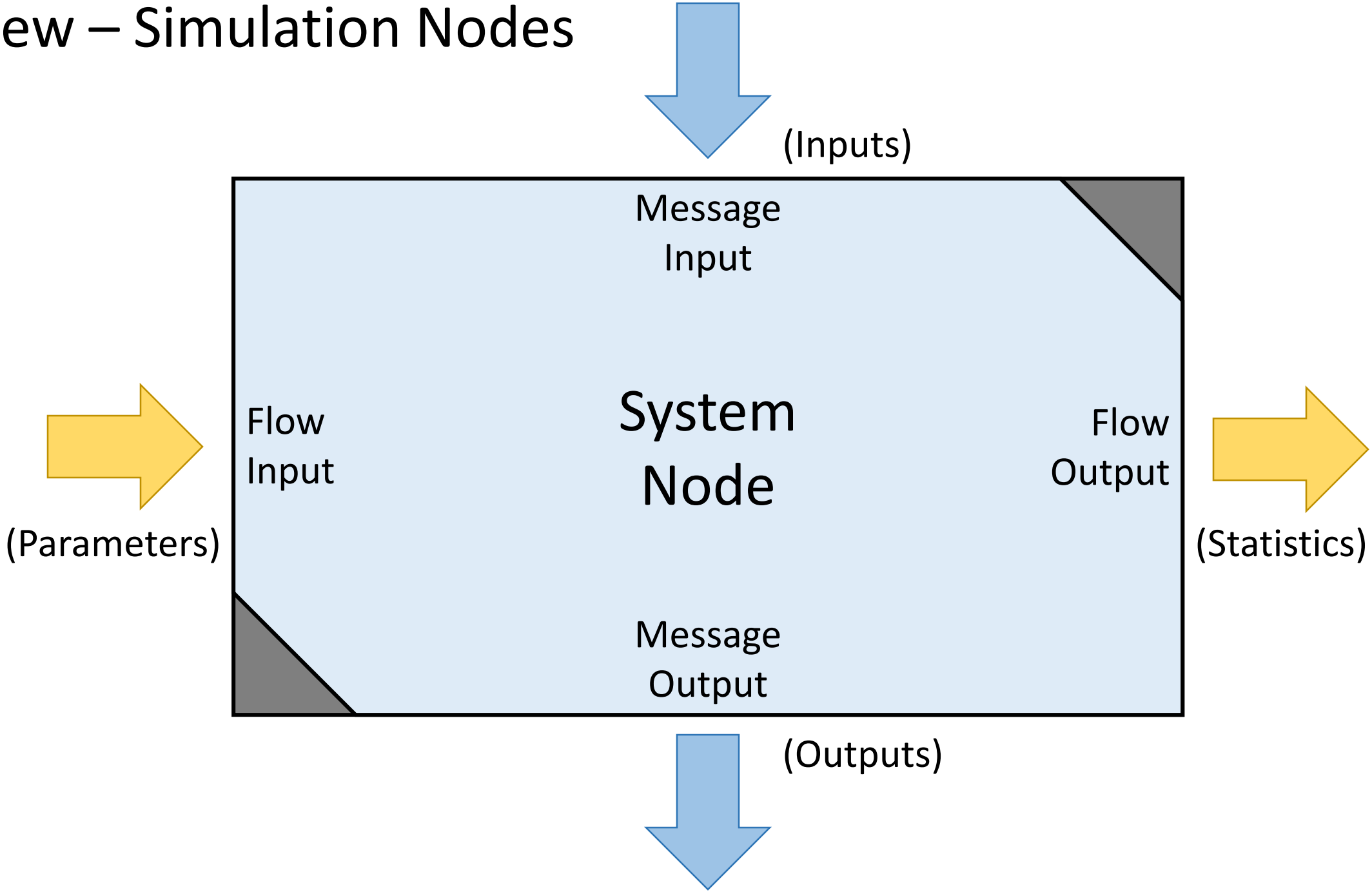

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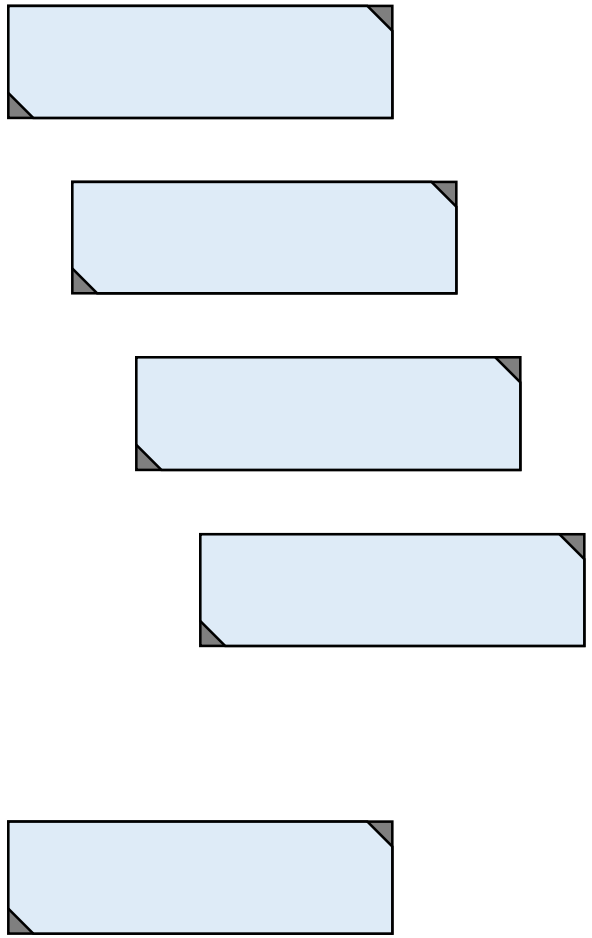
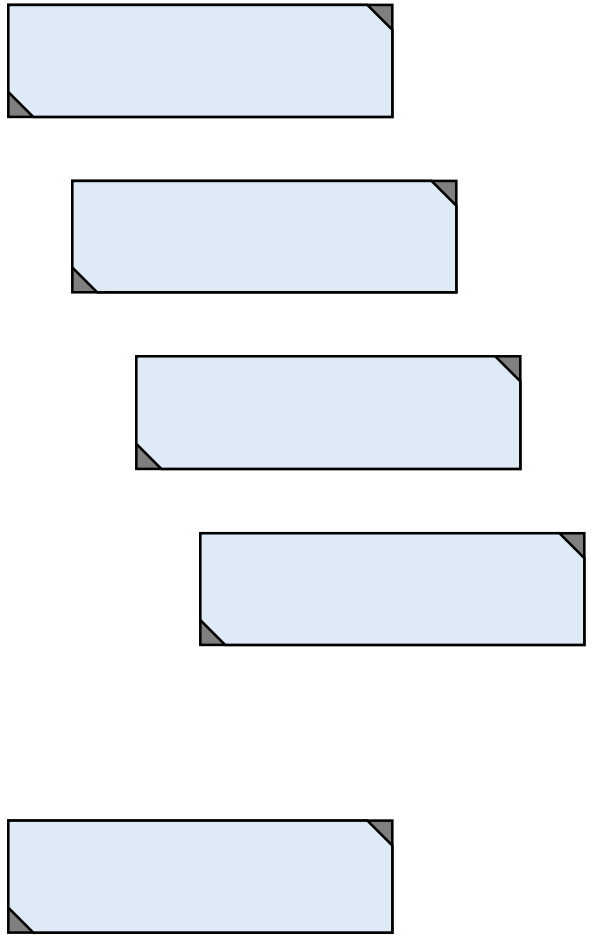


Review – Atomic Nodes



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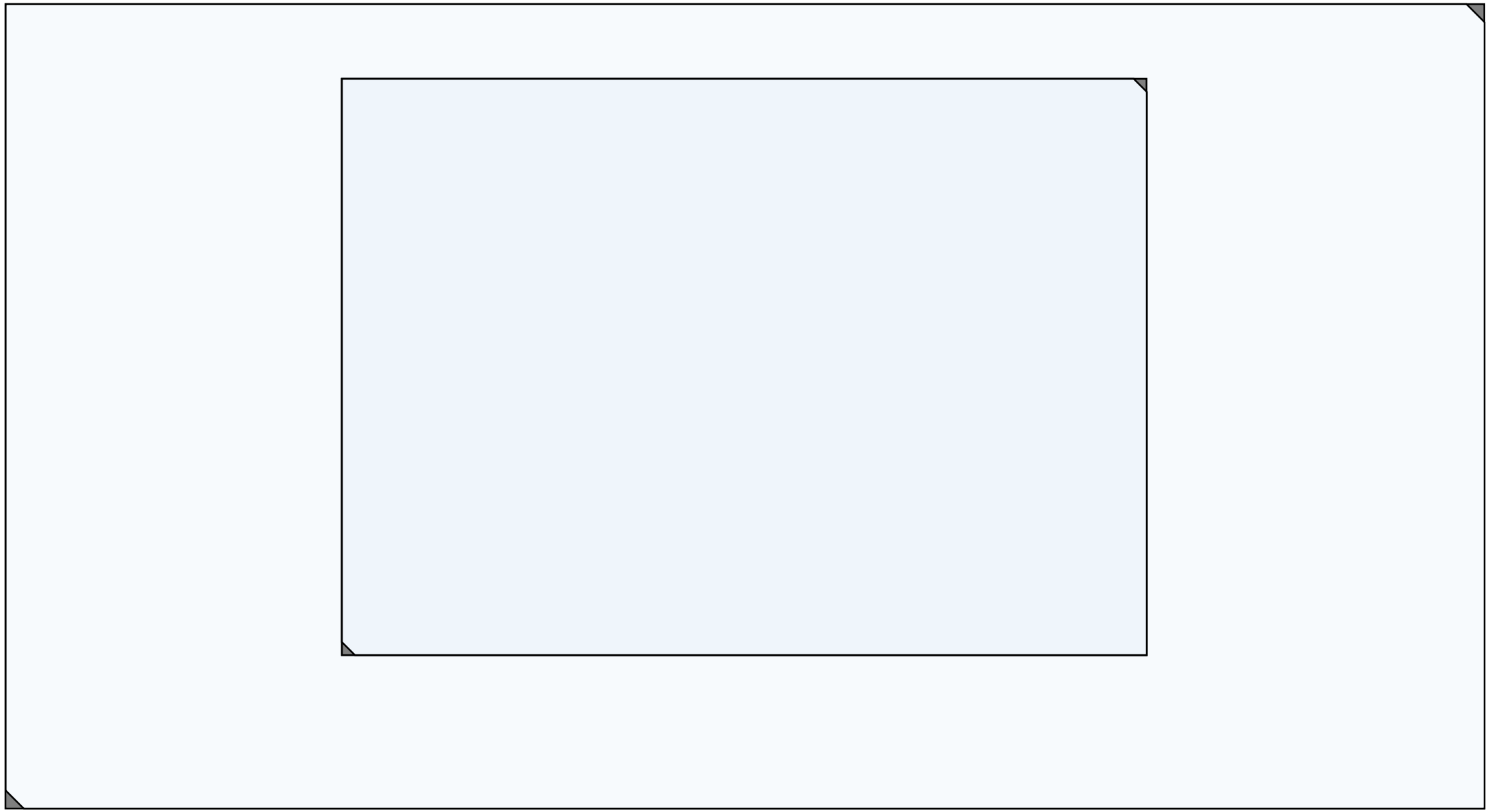

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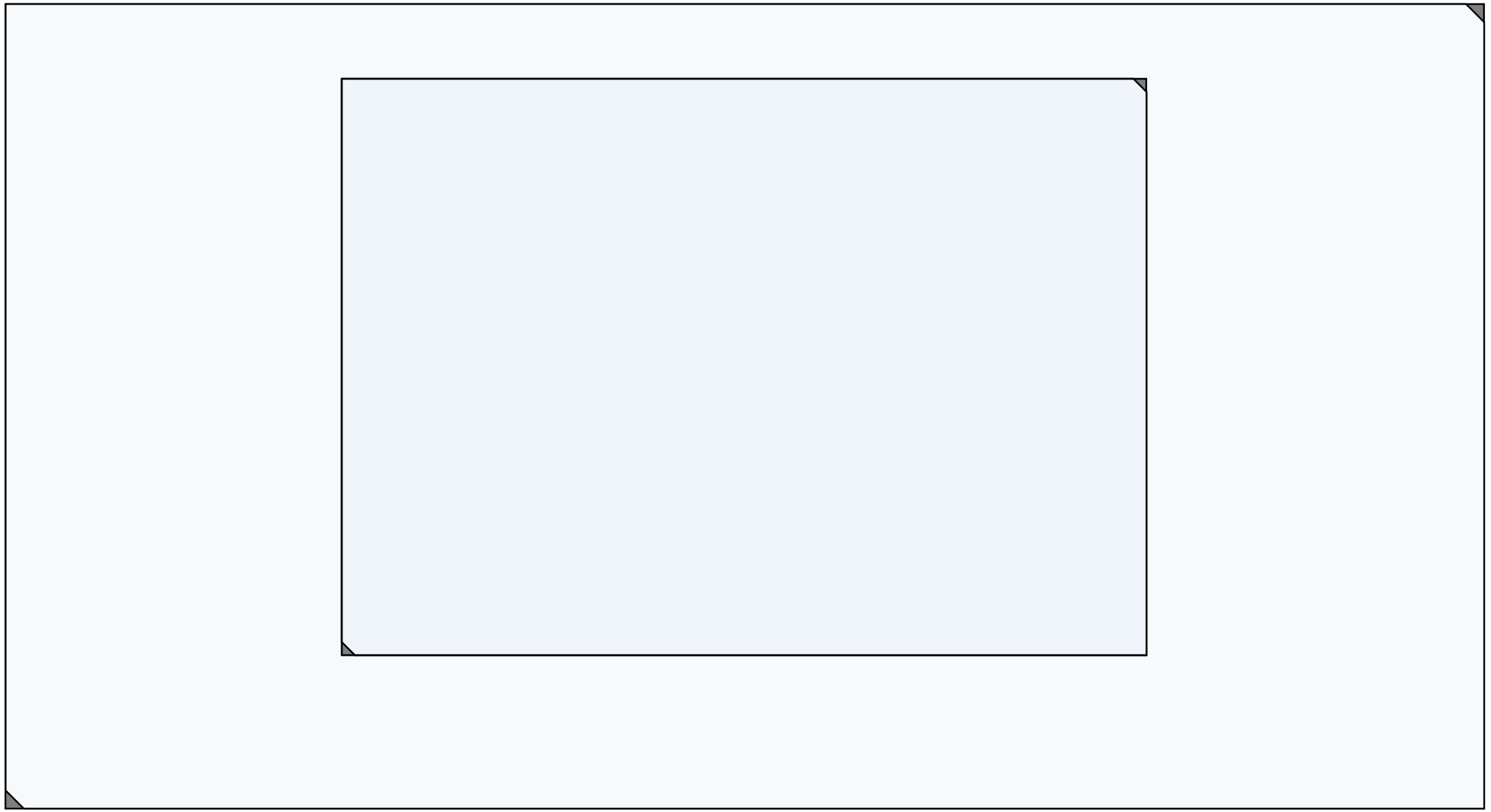

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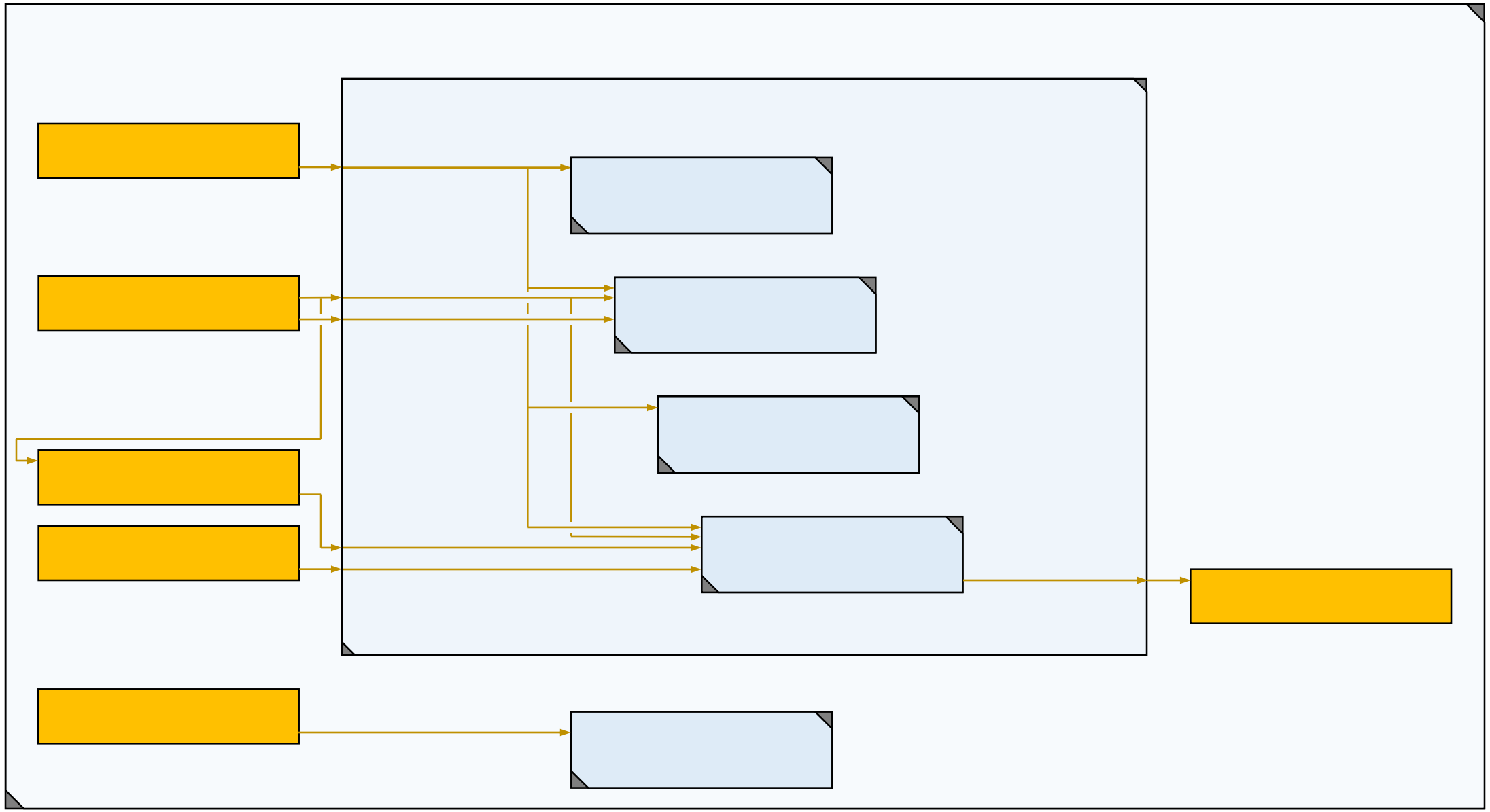
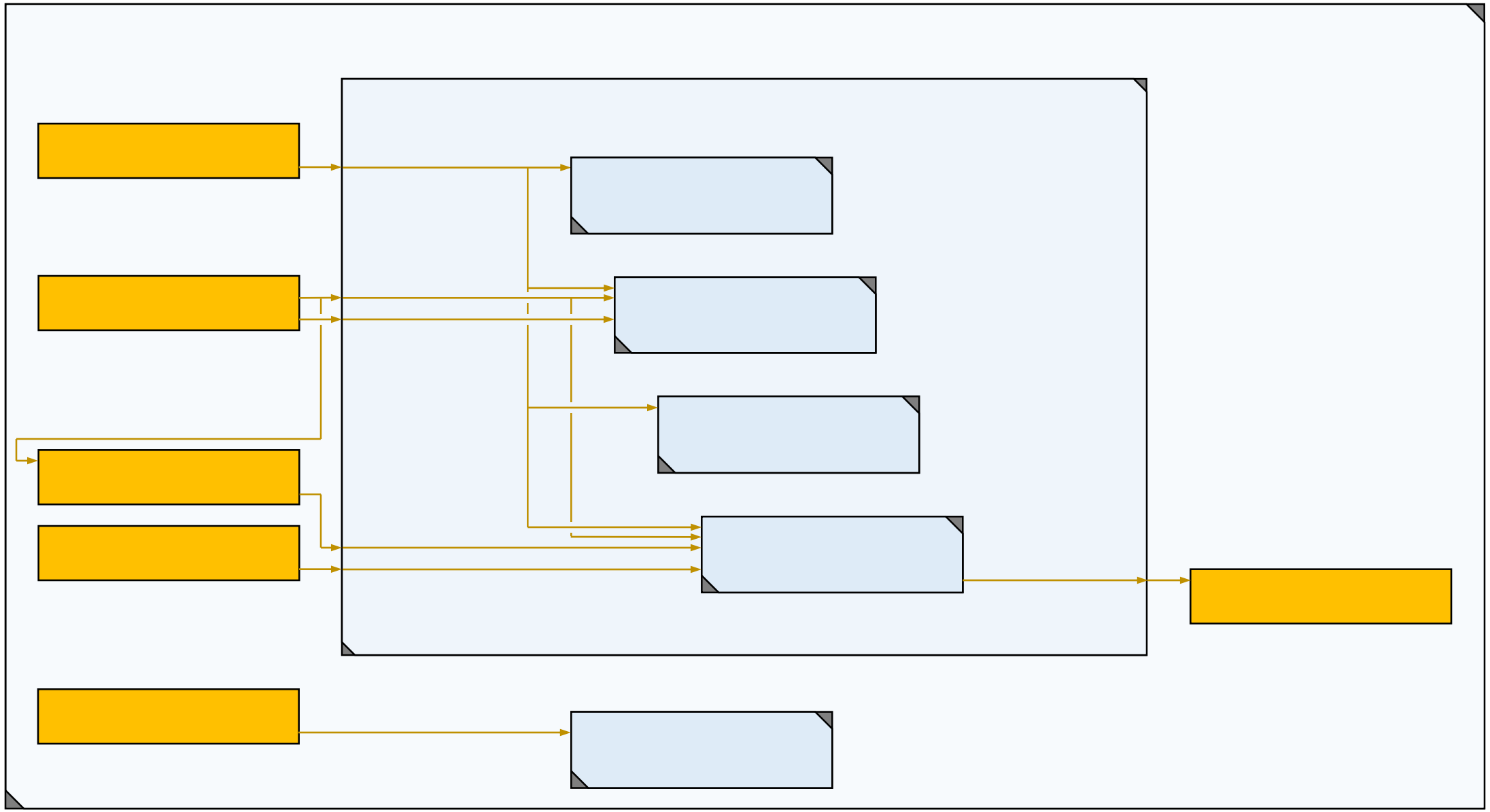


Review – Flow Links



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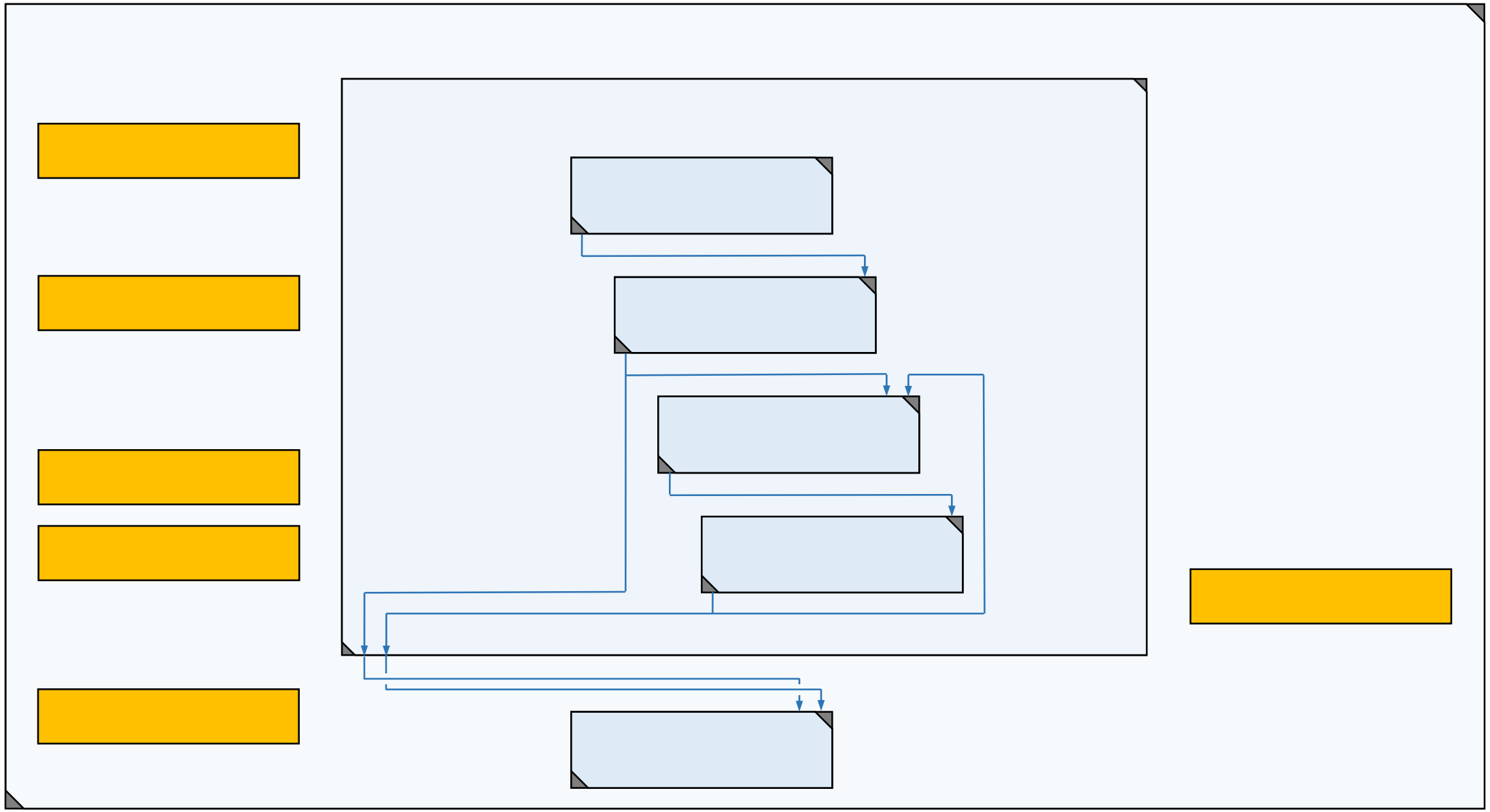
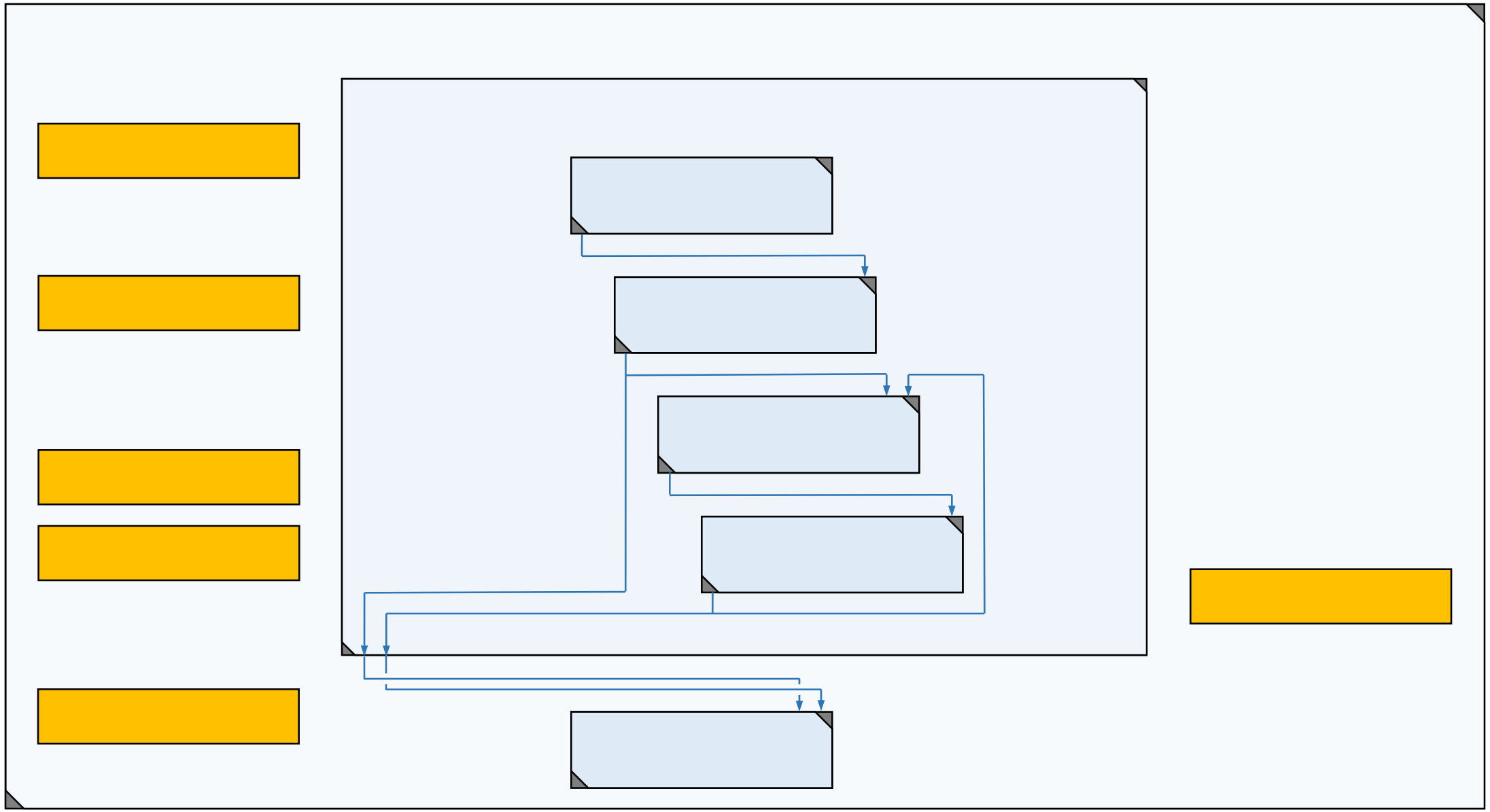
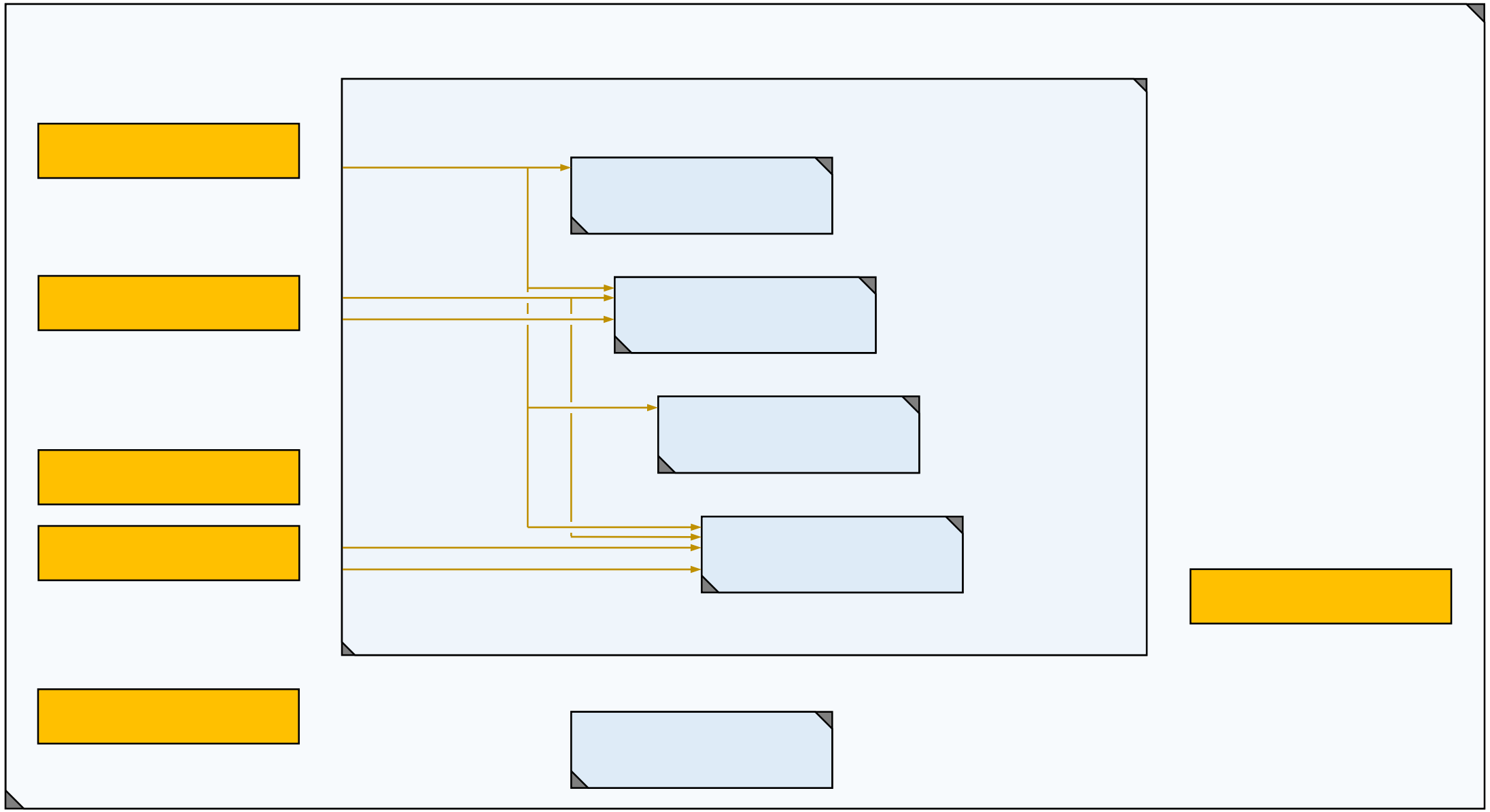


Review – Message Links



Review – ?



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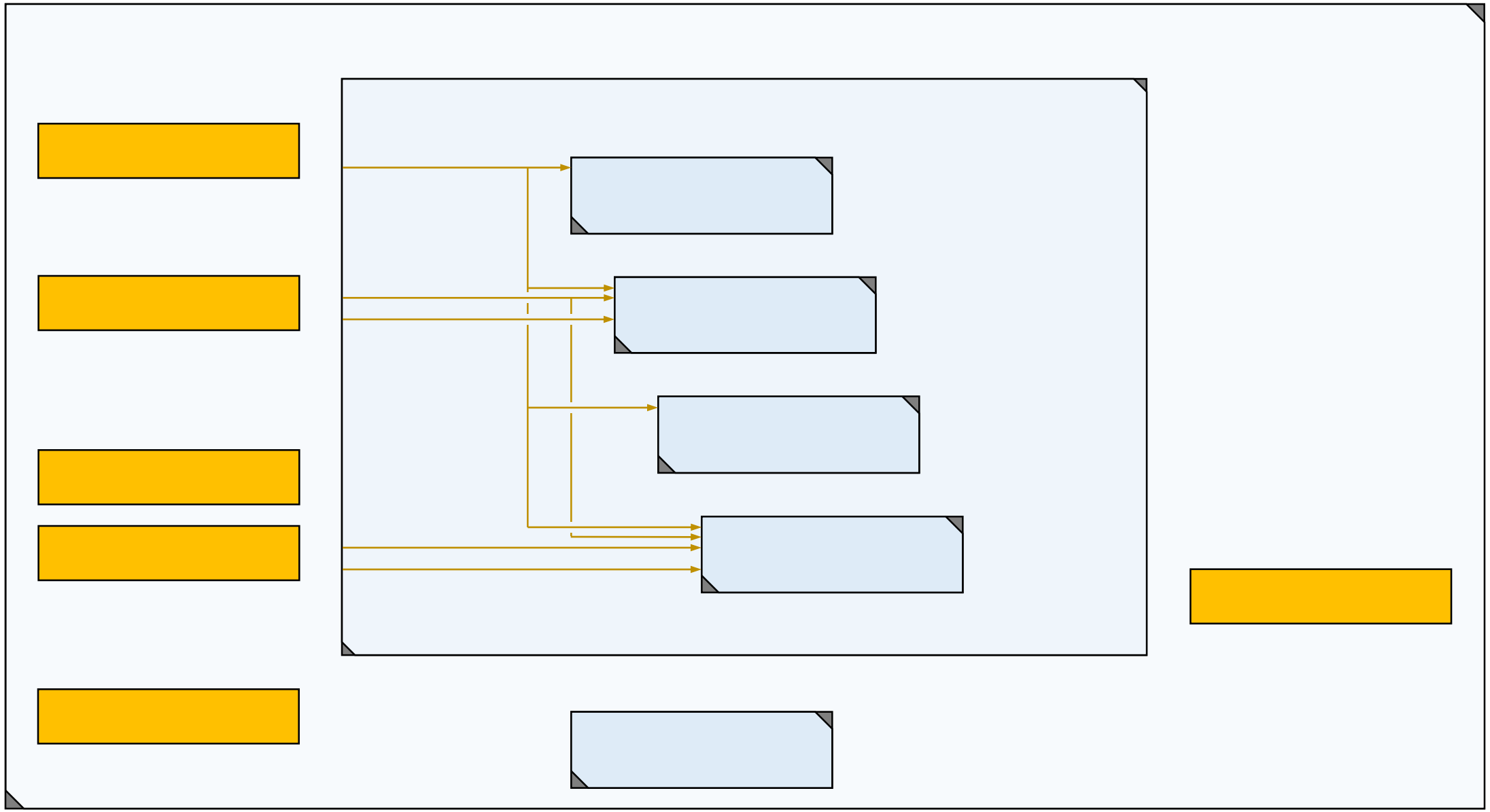

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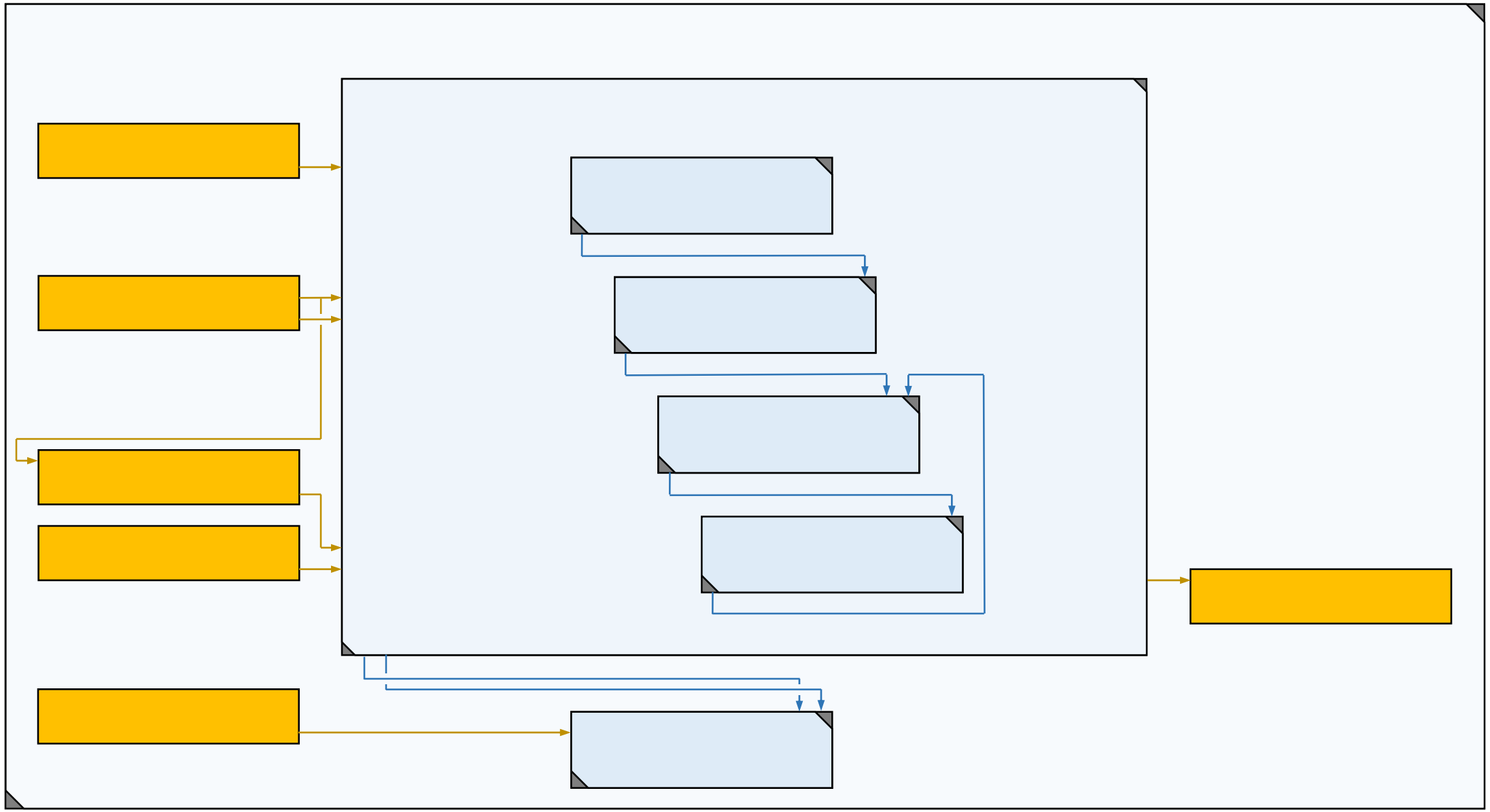

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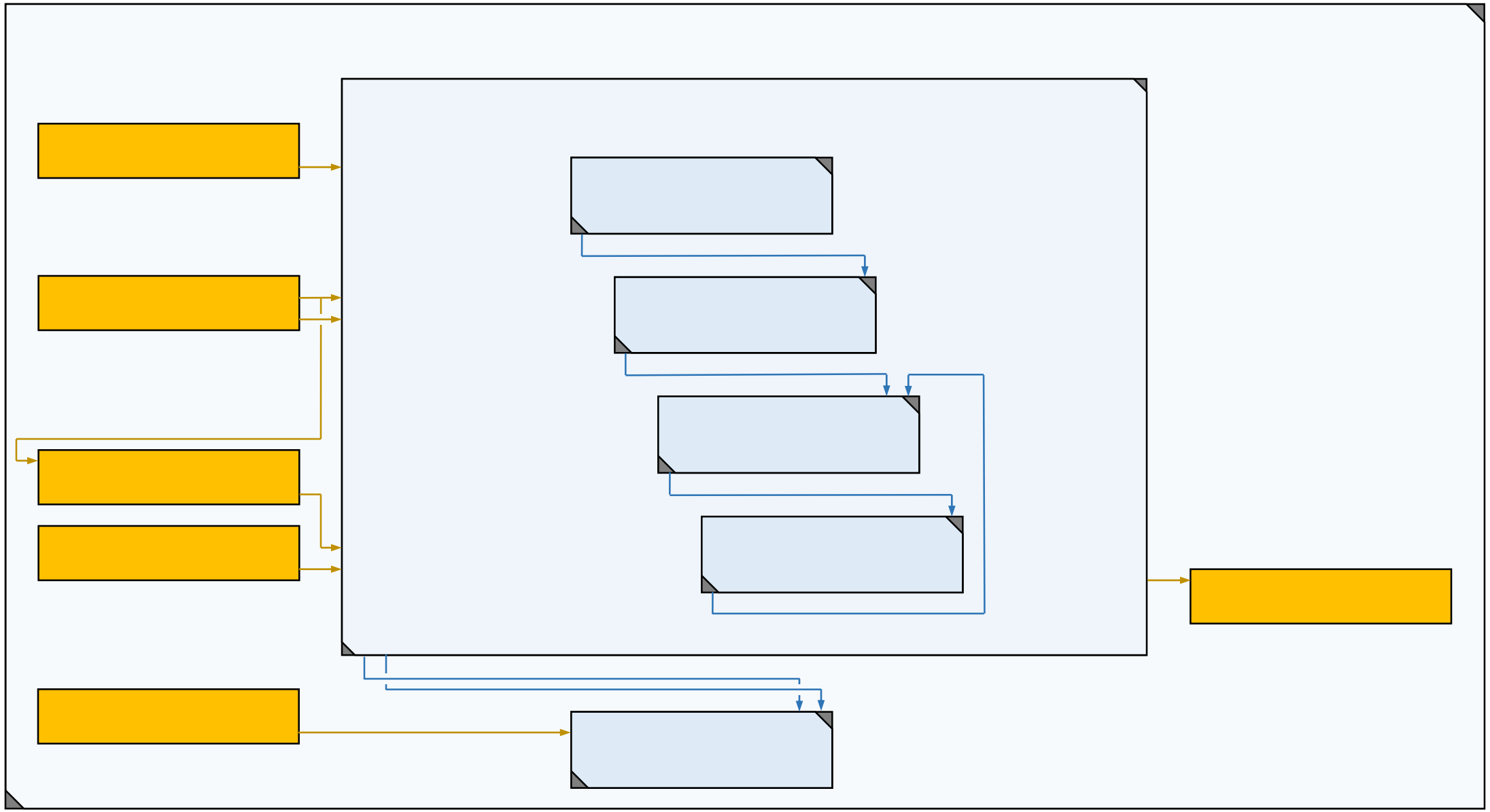

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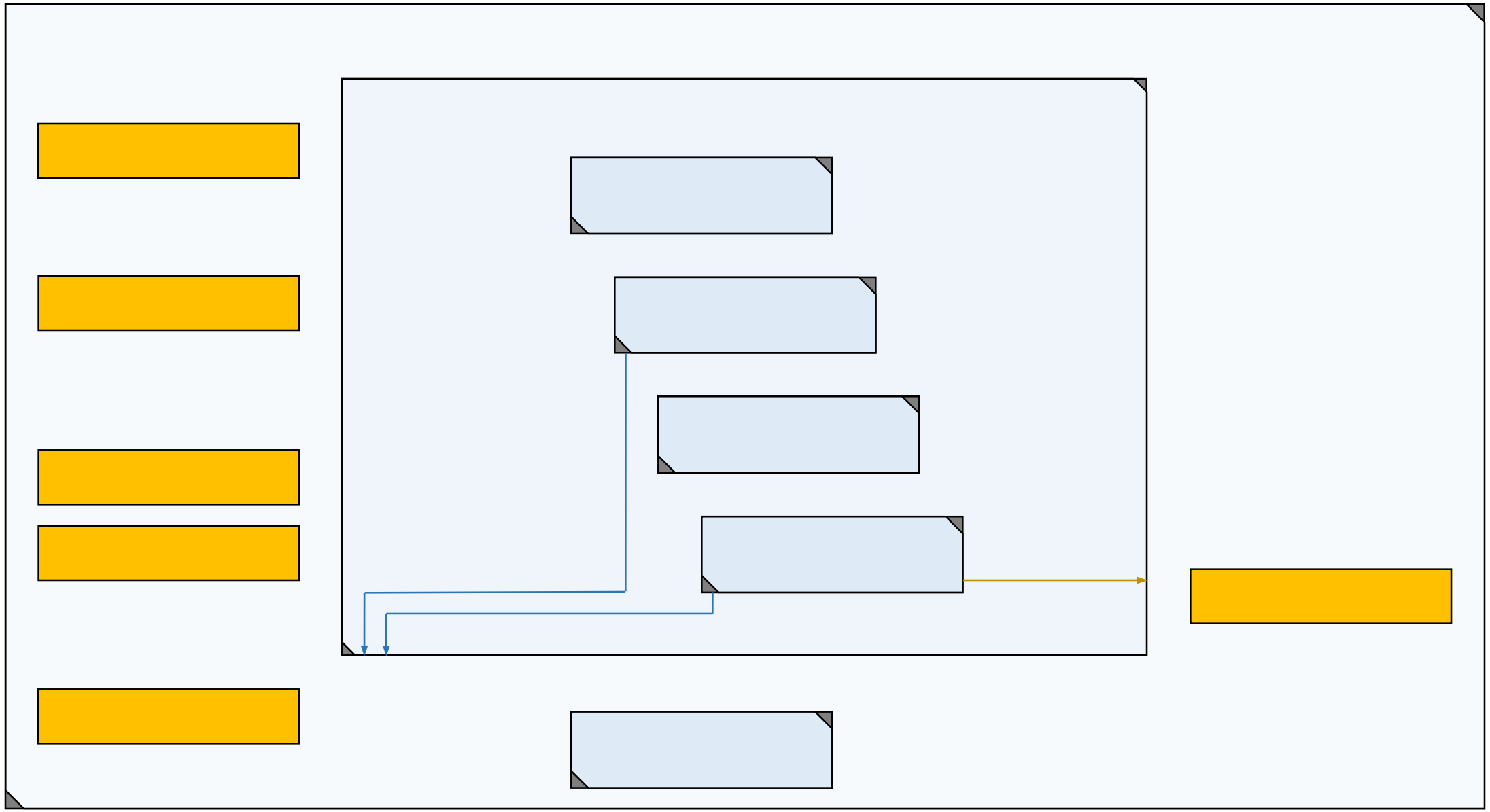

Review – Outward Links