# Mission Specification: Automating science operational decisions

Each agent has a **mission** defined a s a set of objectives. An **objective** is defined as a tuple where is the relative weight of that objective to the agent’s mission; is the primary geophysical parameter/data product (e.g., chlorophyll-Aconcentration); and is a set of measurement requirements.

## Mission Requirements for Attribute Representation

A (measurement) **requirement** is defined by a tuple where is an attribute of the data product (e.g., horizontal spatial resolution) and is a **preference function** that relates values of a given requirement’s attribute to a fitness score between 1 and 0.

The definition of can vary depending on the nature of the attribute being characterized by the requirement. One approach could include the use of threshold and score values ( and respectively) to define a preference mapping function. Specifically, could be an ordered list of threshold values and is an ordered list of scores . For discrete attributes, may contain all possible values and the score for each value. For continuous attributes, is interpolated from , .

* **Spatial coverage** requirements define the region of interest for the observations, which can be specified as a list of *lat, lon* points or as a coverage grid defined over a region of interest. For regions larger than a point, spatial sampling can be specified with individual requirements for in horizontal and or vertical spatial resolution, as applicable.
  + in this case could be a binary preference function that returns if any of the desired targets are within the observed targets and otherwise.
  + A different preference function could also be selected such that it benefits the simultaneous observation of multiple desired targets by returning the percentage of desired targets currently being observed .
* **Temporal coverage** requirements define the extent of time during which observations are to be performed. For continuous monitoring objectives, this maybe a long time(e.g., a month), whereas for event-based objectives, it may be a much shorter duration depending on the event type (e.g., a few hours). During this time window, the temporal sampling with which observations are to be performed can be specified.
  + For continuous monitoring objectives, one can simply define a **revisit time requirement** with the corresponding preference function. Note that the preference function specified for revisit time implicitly provides a way to value re-observations of the same point or region. The marginal value of the next observation is the slope of the preference function at the current revisit time.
  + Alternatively, one can explicitly provide a preference function as a function of the number of observations of the same point. The latter can be more natural to define for event-based objectives.
* **Observation performance attributes** can also be used to specify requirements. Some of the most common ones may be spectral coverage and sampling, radiometric resolution, or signal-to-noise ratio. Higher-level attributes can also be used, such as day-night or all-weather capability. Continuous or discrete preference functions can be defined for these and other attributes using the method described above, even for more qualitative attributes as demonstrated in the VASSAR papers (Selva et al., 2014; Selva & Crawley, 2013).
  + For example, a **spatial resolution** requirement could be chacarterized by a smooth monotonically decreasing function, such as a sigmoid or generalized rational decay, fitted to some threshold and score values (i.e., and ).
* **Capability attributes** characterize whether a satellite’s instruments or control systems can support the observation of a desired geophysical parameter. These capabilities can be represented through **measurement requirements**, using preference functions that quantify how well an agent’s capabilities align with those required by a mission objective.
  + For example, the ability of an instrument to observe a given objective’s primary parameter can be modeled as a simple membership check: whether belongs to a reference set of valid instruments . A binary preference function can then express the instrument’s fitness for the objective.
  + This functionality and evaluation can be facilitated and expanded through knowledge graphs or other formal knowledge representations.

## Geophysical Events of Interest

An event of interest can be detected by an agent. An **event** is defined by a tuple . It is initially characterized by a type, location , and detection time . On board data processing is used to determine an expected duration and severity .

## Tasks

### Default Mission Tasks

During nominal operations, satellites must schedule observations based on their default mission objectives. Any possible observation window is then represented as a default observation task which indicate the the relevant parameter to be obeserved at location at a time or time interval with a priority to satisfy a given mission objective . These tasks are not shared between agents and are only considered by the agent generating them based on its own mission objectives.

### Event-Driven Tasks

To respond to event , one or more tasks are generated by the agent that discovered the event which require measuring the relevant parameters at location and time or time interval , with a priority of . This priority is tied to the severity of the event being observed. In addition, the agent can include the relevant objective from its mission and the description of the detected event in the task, to include any relevant requirements.

One task is created for each event’s geophysical parameter (or desired instrument types, by using level 1 data products such as TIR radiances). The requirements for cross-registered co-observations of the event (of different parameters, or from different sensor types) are managed by creating the corresponding task requests with the same location and time intervals.

## Evaluating Tasks using Mission Objectives

#### Mapping Objectives to Tasks

Given an observation task , the agent must identify or create a relevant event-based objective . This is captured by the matrix which maps tasks to objectives by assigning a fitness value where the higher the value, the more relevant an objective is to a given task.

If all agents know a priori about all possible task and event types and have objectives defined for each of them, the creation of this matrix is trivial and the corresponding objectives can be used as is. If agents have different objectives and the agent receiving a task request does not have an objective related to that event, it must create a new objective. The weight of the new objective can be determined based on the weight of the closest existing objective in terms of semantic similarity, using ametric supported by a large language model that leverages the KG. The rest of the new event-based objective information can be copied from the task request, if it is provided. Otherwise, it can also be inferred using a similar approach. For example, it is reasonable to assume that to respond to events of interest about rivers, one may need similar spatial resolution.

#### Evaluing Task Performance

Once an task is mapped to an existing or new objective, its value can be determined by relating its performance to an agent’s mission objectives. The task and the agent together determine the geometry of the observation, which can be used to compute the performance attributes . The performance of an observation is then defined as the product of the utilities of all the performance attributes by agent for task for all for all mission requirements in a given mission objective :

#### Calculating Task Value and Utility

Since some tasks have higher priority than others, the preference functions are objective-specific,and not all tasks are relevant to all objectives, the value of agent performing task to the agent’s objective is computed as:

Finally, for the purposes of task planning and scheduling, we may want to consider the cost of performing a task in addition to its scientific value. Therefore, we define a utility function that in addition to consider the cost of performing the task, with some weight to define the relative importance of science vs cost. For satellite constellations, this would typically represent the cost of the slewing maneuver needed to point at the location of the task. In that case, it is reasonable to use a very small (but non-zero)since energy can be regenerated “for free” with solar panels, but we still want to incentivize efficiency in the plan.

## Definitions Summary

| Expression | Definition |
| --- | --- |
|  | Mission |
|  | Objective |
|  | Relative objective weight |
|  | Primary geophisical parameter/data product |
|  | Objective Requirements |
|  | Measurement Requirement |
|  | Attribute of the data product (e.g., horizontal spatial resolution) |
|  | Performance attribute |
|  | Attribute preference function (maps performance attribute to requirement satisfaction value between ) |
|  | Requirement satisfaction threshold values |
|  | Requirement satisfaction score values |
|  | Event |
|  | Event detection time |
|  | Expected event duration |
|  | Event severity |
|  | Default observation task |
|  | Event-driven observation task |
|  | Desired observation location |
|  | Task availability time or interval |
|  | Task priority (or reward) |
|  | Mission objective relevant to a task |
|  | Index for satellite |
|  | Index for task |
|  | Index for objective |
|  | Index for performance attribute |
|  | Relevance of task to objective |
|  | Performance of an observation by agent of task on objective |
|  | Value of agent performing task |
|  | Utility of agent performing task |
|  | Cost of agent for performing task |
|  | Task cost normilizing parameter |