

Governing Open Complex Giant Generative Relational Systems beyond Representation and Reach

A Synoptic Discussion of Systems, Scales, and Arrangements

Wanhong Huang

huangwanhong@serendip.ngo

Abstract

Three companion papers establish results about the governance of systems that exceed what any party can represent or reach, and a fourth constitutes the class of problems such systems present. This paper adds the survey of the systems themselves that the four leave to be made. It places the systems of human–nature and human–cosmos relation on a landscape whose axes are the two limitations that define the class, the accessibility of a system to representation and the reach of deliberate intervention within it, with the reversibility horizon of a foreclosure as a third dimension. It then overlays the arrangements presently governing each region. The survey draws its vocabulary, in the standing of an inspiration, from the classification of open complex giant systems developed by Qian Xuesen and colleagues, under which a system is giant by the number of its subsystems, complex by the variety of their kinds together with a hierarchical structure among them, and open by exchange with an environment. Each system surveyed is identified as an open complex giant system by naming the characteristics it exhibits, and the classification serves the survey solely as that characterisation: the paper is a discussion in social science, the tradition's own methodological programme addresses a question proper to it, the organised combination of dispersed knowledge, and the question treated in this paper, what stands outside what any party has recorded, is a different one. A dedicated section treats heterogeneity, a term the series has used and which admits no description-independent statement, since a field is one collection of kinds under one description and another under another. The paper adopts a relational definition, under which a field is heterogeneous with respect to a party when no common measure over its participants is available to that party, and records the consequence that heterogeneity so defined is a condition of the relation between a field and a party in place of a property of the field. Three findings follow from the landscape: the systems cluster in ways that cut across the domains by which governance is presently organised; the arrangements are dense where visible damage has occurred and sparse where it has not; and the results of the companion papers hold over determinate and differing regions.

Keywords: open complex giant systems; environmental governance; orbital governance; heterogeneity; generative relational governance.

Draft. This is a working draft. It is circulated for comment, and its arguments, formulations, and open questions are subject to revision. Correction and criticism are welcome at huangwanhong@serendip.ngo.

Licence. © 2026 Wanhong Huang. This work is licensed under a Creative Commons Attribution–NonCommercial 4.0 International Licence (CC BY-NC 4.0).

You are free to share and adapt the material, under the following terms: you must give appropriate credit, provide a link to the licence, and indicate if changes were made; and you may not use the material for commercial purposes. The full text of the licence is at <https://creativecommons.org/licenses/by-nc/4.0/>.

Use of generative artificial intelligence. Generative AI assistants (Anthropic’s Claude, OpenAI’s ChatGPT, and Google’s Gemini) were used extensively in preparing this manuscript: for literature survey, for drafting prose from the author’s specifications, for adversarial review of the argument, and for consistency and citation auditing and typesetting. No simulation or empirical result is used in this paper, and its arguments are discursive throughout; the two figures are qualitative diagrams of the placements argued in the text, the scripts drawing them accompany the source, and the table summarises the survey. Formulations and objections arose in the course of that exchange as well as from the author. Every claim, argument, and citation was reviewed and decided by the author, who is responsible for the content and for any errors. Bibliographic details are to be verified against the primary sources before reliance.

Suggested citation: Wanhong Huang, *Governing Open Complex Giant Generative Relational Systems beyond Representation and Reach: A Synoptic Discussion of Systems, Scales, and Arrangements*, working draft, 2026.

1 Introduction

This section states what the paper supplies, states why the companion papers leave it unsupplied, states the standing in which the paper draws its vocabulary from an existing tradition, and sets out the order of the argument. The method is comparative and descriptive for the construction of the landscape and the findings drawn from it, in Sections 5 to 10, and analytical for the treatment of heterogeneity in Section 4.

Four companion papers address the governance of systems whose extent exceeds what any party can represent and whose condition exceeds what any party can alter.

One establishes a criterion allocating the burden of justification where a course would irreversibly foreclose the generative capacity of a trajectory other than the acting party's own. A second establishes that the capacity to determine the state of such a system is acquired through use of it, so that the party best equipped to determine that a system stands near a critical value is the party such a determination favours. A third establishes that existing schemes hold no doctrine of withholding a possibility while retaining its availability. A fourth constitutes the class of problems these systems present and states a research agenda for it.

Each addresses a determinate question and none surveys the systems. A reader completing the four holds a criterion, a structural result, a taxonomic finding and a constituted problem class, and holds no account of what systems are at issue, at what scales they stand, which of them are presently governed, by what arrangements, and where the arrangements are absent. This paper supplies that account.

The account could take the form of a catalogue, and a catalogue would be of limited value. The systems at issue are named readily enough, and a list of them settles nothing.

The survey offered in this paper places the systems on a landscape whose axes are the two limitations that constitute the class. One axis is the accessibility of a system to representation by a governing party. The other is the reach of deliberate intervention within it. A third dimension records the horizon over which a foreclosure within the system admits reversal.

The placement performs work that a catalogue does not. It establishes which systems stand near one another under the constitutive limitations in place of under the domains by which they are conventionally sorted, it exhibits which regions of the landscape the existing arrangements occupy, and it locates the results of the companion papers, each of which holds over a region and none of which holds over the whole.

A vocabulary is required for the systems so placed, a classification adequate to the purpose exists, and the paper draws on it in the standing of an inspiration.

Qian Xuesen and colleagues distinguish systems by the number of their subsystems, by the variety of subsystem kinds together with the presence of hierarchical structure among them, and by whether the system exchanges with an environment. A system with a very large number of subsystems is giant; a giant system whose subsystems fall into many kinds standing in a hierarchy and coupled in complex relations is a complex giant system; and such a system exchanging with its environment is an open complex giant system.

The present paper is a discussion in social science and political philosophy, and the

classification is received from the tradition as a characterisation and a vocabulary. Each system surveyed is identified as an open complex giant system by naming the characteristics it exhibits, and nothing further is asked of the classification: no placement is presented as an application of the tradition's criteria in their technical sense, and no result within systems science is claimed. The tradition developed a methodological programme together with the classification, and the question that programme addresses, the organised combination of knowledge dispersed across disciplines and experts, is distinct from the question the companion papers address, which concerns what stands outside what any party has recorded. Section 3 sets out the classification, states the standing in which it is drawn on, and states the relation between the two questions, offering no assessment of the programme.

One further term requires attention before the survey begins. The companion papers use the term *heterogeneous* to describe the fields at issue, and the term admits no description-independent statement.

Under one description the field is a distribution of matter and energy in spacetime and its participants are of one kind throughout. Under another its participants are organisms, artefacts, atmospheres and orbits, and the kinds are many. Nothing in the field settles which description is correct, so an assertion that a field is *heterogeneous* asserts nothing until a describing party is specified.

Section 4 treats the term at length. It records that the variety of kinds together with hierarchical structure is what *complex* already denotes in the classification adopted, so that the field-side work the term was performing is performed without it. It then supplies a relational definition for the work that remains, under which a field is *heterogeneous* with respect to a party when no common measure over its participants is available to that party, and it records that heterogeneity so defined is a condition of the relation between a field and a party in place of a property of the field.

The order of the argument is as follows. Sections 2 to 4 fix the object and the vocabulary: Section 2 states the scope and the positions declined. Section 3 sets out the open complex giant system classification, states the standing in which the paper draws on it, and states the relation between the tradition's question and the present one. Section 4 treats heterogeneity.

Sections 5 to 7 construct the landscape. Section 5 states the axes and the grounds for choosing them. Section 6 places the systems. Section 7 overlays the arrangements.

Sections 8 to 10 state the findings. Section 8 treats the clustering and the institutional misfit it exhibits. Section 9 treats the regions the arrangements leave unoccupied. Section 10 locates the results of the companion papers.

Sections 11 and 12 close, the former arguing the positions declined and the latter stating the limits of what has been established.

2 Scope of the Account and the Restrictions It Accepts

This section fixes what the paper surveys, states the restrictions confining the survey, states its relation to the companion papers, and states the positions declined. Its role in the paper

is boundary-fixing: every later section works within the scope stated in this section, and the relation to the companion papers stated at §2.3 determines which of their results the survey may use. The section is arranged as follows: §2.1 fixes the object of the survey, §2.2 states the restrictions, §2.3 states the relation to the companion papers, and §2.4 announces the four positions declined, whose arguments Section 11 supplies.

2.1 The Object of the Survey

The object is the set of systems within which human activity stands in relation to the wider natural and cosmic field, together with the arrangements presently governing activity within them.

A system enters the survey where it exhibits the characteristics by which the classification of §3.1 identifies an open complex giant system, and where human activity within it bears on the continued operation of participants other than the acting party. Watersheds, airsheds, forests, ocean basins, the atmosphere, orbital shells, the geostationary belt, cislunar space, the night sky and the distributed chemical burden are the members treated in Section 6.

2.2 Restrictions Accepted by the Account

The account is restricted in four respects, and each restriction narrows what a reader may take the placements to establish.

The first restriction is that the survey places systems and assesses no arrangement. Whether an arrangement governs its region well is a question the survey does not reach, and Section 7 records where arrangements stand in place of how they perform.

The second restriction is that the survey is qualitative throughout. The axes of Section 5 admit no measurement the paper supplies, the placements are comparative, and §12.1 records the cost.

The third restriction is that the object is systems and not domains of scholarship. The traditions addressed to each region are noted where they bear on a placement, and the companion paper treating those traditions establishes what each requires.

The fourth restriction is that the survey treats the present state of the arrangements and offers no history of how each arose. Where a placement turns on the date at which observation or use began, the date is stated and the history is otherwise left aside.

2.3 The Relation to the Companion Papers

Four companion papers stand to this one as the establishment of results stands to the survey of a terrain.

Nothing in this paper re-argues any of them. Section 10 locates each result on the landscape and states the region over which it holds, and the locating is the paper's principal use of the companion work.

A reader rejecting every companion result may hold the landscape of Sections 5 to 7 and the findings of §8 and §9, which rest on the placements and on the arrangements overlaid.

2.4 The Positions Declined

Four positions are declined in the present subsection, and the argument for each declination is given in Section 11, after the results on which it depends have been established.

The first declination is of completeness for the survey. Systems exhibiting the same characteristics are omitted, §12.2 records which, and the findings are stated in a form that survives the omissions.

The second is of a metric for either axis. A metric would license comparisons the qualitative placements do not support, and the temptation to supply one is treated at §11.2.

The third is of an assessment of the tradition drawn on at Section 3. The relation stated there is a difference between the tradition's question and the present one, and an answer to the tradition's question, however complete, is compatible with everything this paper states.

The fourth is of a proposal for the regions the survey finds unoccupied. The companion papers establish why such a proposal would be premature, and §11.4 states the ground.

3 The Classification of Open Complex Giant Systems and the Use Made of It

This section sets out the classification the paper draws on, states the standing in which it is drawn on, gives a brief account of the methodological programme the tradition developed together with the classification, states the relation between the tradition's question and the question of the present series, and closes by naming the elements the paper takes as its inspiration. One point governs the whole section and is stated first. The present paper is a discussion in social science and political philosophy. Its results, its methods and its judgments all belong to social science, and the tradition's own field is left entirely to the tradition. The classification is received as an inspiration and a vocabulary from a body of thought that treated systems of this constitution with a seriousness the paper acknowledges, and every statement made about the tradition below is intended as restatement, made briefly and with the caution a brief restatement of an extensive tradition requires. Its role in the paper is to fix the vocabulary and its standing before any system is placed, so that no placement in Sections 5 to 7 is read as a claim within systems science. The section is arranged as follows: §3.1 sets out the classification, §3.2 states the standing in which it is drawn on, §3.3 gives a brief account of the methodological programme, §3.4 states the relation between the tradition's question and the present one, and §3.5 names the inspiration taken.

3.1 The Classification

Qian Xuesen and colleagues proposed a classification of systems drawn from the constitution of a system in place of from its subject matter [7].

As the tradition presents it, a system whose subsystems are few and whose relations among them are simple is a simple system. A system whose subsystems are very numerous is a giant system. A giant system whose subsystems fall into few kinds and stand in simple relations is a simple giant system, and a laser is the instance the tradition offers. A giant system

whose subsystems fall into many kinds, stand in a hierarchical structure, and are coupled in complex relations is a complex giant system. A complex giant system exchanging with an environment is an open complex giant system, and the tradition places social systems, the human body and the biosphere among them.

Three features of the classification bear on the use the present paper makes of it.

The first is that the criteria are stated over the constitution of a system and not over its domain, so systems conventionally sorted into separate fields may fall into one class.

The second is that the variety of subsystem kinds is a defining criterion of complexity, together with hierarchical structure among those kinds. This bears directly on the term the introduction retires, and the point is developed at Section 4.

The third is that openness is a separate criterion, so that a system may be complex and giant while closed. The systems surveyed in this paper are open throughout, and the openness is what makes the boundary-drawing difficulty of the companion agenda paper unavoidable.

3.2 The Standing in Which the Classification Is Drawn On

The classification is drawn on in the standing of an inspiration, and two features of it supply the inspiration.

It offers a stated characterisation in place of an impression. A field described as complex in the ordinary sense has been described by a word that admits any use. A field identified as an open complex giant system has been characterised by the constitution the classification names: very many subsystems, subsystems of many kinds standing in a hierarchical structure and coupled in complex relations, and exchange with an environment. The survey of Section 6 identifies its systems in exactly this manner, by naming the characteristics each exhibits, and asks nothing further of the classification. No placement in this paper is presented as an application of the classification's criteria in the tradition's own technical sense, and none is presented as a result within systems science.

It stands within a tradition that recognised systems of this constitution as a subject in their own right. The recognition matters to the present series, since the systems treated in this paper, watersheds and ocean basins, orbital shells and the distributed chemical burden, are ordinarily studied under the domains that divide them and are rarely held together as one class. The tradition held such systems together, gave the class a name, and directed sustained attention to the difficulty the class presents. The present paper writes in acknowledgment of that recognition and takes the name with gratitude.

3.3 The Methodological Programme Developed with the Classification

The classification was proposed together with a methodology, and the two are presented together in the tradition's own literature.

The methodology is meta-synthesis, developed as an approach proceeding from the qualitative to the quantitative [3]. As the tradition presents it, a system of this kind is approached through the organic combination of three components: a body of experts drawn

from the disciplines bearing on the system, the data and information available concerning it, and computational and networked machinery. Its institutional form is a hall for workshops of meta-synthetic engineering, within which the three components are brought into sustained interaction, and its methodological self-understanding is that a systems approach constitutes a dialectical unification of holism with reductionism.

The restatement given in this subsection is brief and the tradition is extensive. The present paper's argument runs independently of the programme's details, an assessment of the programme belongs to systems science, and a reader seeking the programme itself is referred to the tradition's own literature.

3.4 The Relation between the Tradition's Question and the Present One

The question the programme addresses and the question the companion papers address are distinct, and stating the distinction locates the present series. The statement locates, and locating is the whole of what it does; the programme's merits, its reach and its domain remain matters for the tradition's own literature.

The programme addresses the organised combination of what is known. The knowledge bearing on an open complex giant system is abundant, dispersed across disciplines and across experts, and assembled by no single one of them, and the programme supplies an arrangement within which the assembly is brought about. That difficulty is real and severe, and the present series accepts both without qualification.

The companion papers address a different matter: what stands outside what any party has recorded. The companion paper on the allocation of justificatory burden derives, from the finitude and positionality of any representing party, that the portion of a field representable to a party stands properly within the field, and observes that an assembly of every expert and every available datum enlarges the represented portion while the containment remains in force. The companion paper on the determination of system state observes that the capacity to determine the state of such a system rests on records accumulated over time, and that an assembly of every expert holding a record assembles the records that exist, while the records that were not taken are absent from any assembly. Both observations concern the second question and neither bears on the first, since an answer to the first, however complete, leaves the second standing as a further question.

3.5 The Inspiration Taken from the Tradition

Three things are taken from the tradition: its classification, its insistence on treating a class as a class, and its dialectical formulation.

The first, the classification of §3.1, is drawn on throughout the construction of the landscape in Sections 5 to 7, in the manner stated at §3.2: each system surveyed is identified as an open complex giant system by naming the characteristics it exhibits, and nothing further is asked of the classification.

The second, the tradition's insistence that a class of systems be addressed as a class across

the disciplines that divide it, is taken as the survey's governing spirit, and Section 5 states axes over the class in that spirit.

The third, the dialectical formulation under which a systems approach unifies holism with reductionism in place of choosing between them, is taken as a caution against the present series' own temptation. A series establishing that a field exceeds representation may be read as counselling that the field be approached only whole, and the companion papers resist that reading throughout: each states its result over a determinate structure within the field and none appeals to the field entire.

4 Heterogeneity and the Description-Relativity of the Term

This section treats a term the companion papers use and which requires either a definition or retirement. It states the objection, examines three candidate definitions and states why each fails, supplies the definition the series adopts, and states the consequence of that definition for where the condition belongs among the conditions of the class. Its role in the paper is corrective: the term has carried weight throughout the series without a description-independent statement, and the relational definition supplied in this section is the form in which the companion papers are to be read. The section is arranged as follows: §4.1 states the objection, §4.2 examines the definitions that fail, §4.3 supplies the definition adopted, §4.4 states the consequence for where the condition belongs, and §4.5 states the work redistributed upon the term's retirement. The method is analytical.

4.1 The Objection

The companion papers describe the fields at issue as heterogeneous, and the description is offered as a property of the fields.

The description admits no statement independent of a describer. A forest is one collection of kinds under a botanical description, another under a hydrological one, and one kind throughout under a description in terms of matter and energy. The cosmos is a distribution of fields and particles under the description physics supplies, and every part of it is of the same kinds as every other. A party asserting that a field contains many kinds has asserted that the description it employs contains many categories, and a party employing another description asserts otherwise about the same field.

The objection reaches beyond usage into the companion results. Two of the companion results are stated over conditions that include heterogeneity, and a condition that varies with the describer's choice of categories supplies no condition at all.

4.2 The Definitions That Fail

Three definitions suggest themselves, and each fails for a reason the next inherits in altered form.

The first, definition by taxonomic kind, holds that a field is heterogeneous where its participants belong to many kinds within an accepted taxonomy. The definition inherits the

arbitrariness of the taxonomy. It also fails at the boundary the series cares about, since a field containing a thousand species of one phylum would count as more heterogeneous than a field containing an organism, a river and an orbital shell.

A second candidate, definition by scale and temporality, holds that a field is heterogeneous where its participants operate at widely differing spatial scales and over widely differing periods. The definition supplies a continuum in place of a distinction, every field of any extent satisfies it to some degree, and it makes no contact with what the companion results require, since a party may hold a common measure over participants operating at very different scales.

A third candidate, definition by signalling system, holds that a field is heterogeneous where its participants are coupled through modes of signalling admitting no translation among them. The definition is closer and it still refers a description to a describer, since whether two signalling systems admit translation is settled by the resources of the party attempting it.

4.3 The Definition Adopted

Definition 4.1 (Heterogeneity with respect to a party). A field is heterogeneous with respect to a party when no common measure over the participants of that field is available to that party, in the sense that the party holds no scale on which a foreclosure of one participant's capacity and an enlargement of another's may be compared.

Three features of Definition 4.1 carry its adoption, concerning respectively its form, its assessability, and its fit with the companion results.

The first is that it states a relation between a field and a party, and the field considered alone stands outside its subject. The move is the one the companion paper on justificatory burden already makes for epistemic partiality, where the containment of the represented portion within the field is derived from the situation of the representing party in place of from an attribute of what is represented.

The second is that it makes the condition assessable. A party either holds such a measure or holds none, the holding is a fact about the party's instruments and commitments, and a claim that it holds one is answered by producing the measure.

The third is that it supplies what the companion results require. The paper on justificatory burden derives its commitment to plurality from the unavailability of a common measure, and states that a criterion ranking claims would require one. The paper on the determination of system state relies at several points on parties observing one field with different instruments and reaching different estimates. Definition 4.1 is the condition both invoke.

4.4 The Consequence for Where the Condition Belongs

Definition 4.1 carries a consequence the companion agenda paper must accommodate.

That paper groups the conditions constituting its problem class by whether each concerns the field, the governing party, or the relation between them, and it places heterogeneity

first among the conditions of the field. Under Definition 4.1 the placement is wrong. Heterogeneity is a condition of the relation, it belongs with membership, non-discursive participation and asymmetry of address, and the group of field conditions retains criticality and openness, both of which are stated over the field's own dynamics without reference to any party.

The relocation improves the grouping in one respect and costs something in another. It improves it because the remaining field conditions are then uniform in kind, each being a property the field exhibits whether or not it is governed. It costs something because the group of relation conditions was already the group the paper identified as least treated, and enlarging it enlarges the portion of the constitution resting on the least developed material.

4.5 The Term Retired and the Work Redistributed

The term heterogeneous is retired from the description of fields and the work it was performing is redistributed in two directions.

The variety of subsystem kinds together with hierarchical structure among them is what *complex* denotes in the classification of §3.1, and the field-side work is performed there under criteria the tradition has stated. This paper's title uses the classification's term for that reason.

The unavailability of a common measure is what Definition 4.1 denotes, and the relation-side work is performed there. Where the companion papers assert heterogeneity of a field, the assertion is to be read as the second, and §12.1 records that the papers have not yet been revised to state it so.

5 The Axes of the Landscape and the Grounds for Choosing Them

This section states the axes on which the systems are placed, derives the choice of axes from the constitution of the class in place of adopting them for convenience, states the third dimension recorded alongside them, identifies the four regions the axes define and what each signifies, and states what the axes withhold. The regions are displayed in Figure 1. Its role in the paper is foundational for the survey: the axes chosen in this section are what make the landscape an argument in place of a picture, since they are the constitutive limitations of the class and not conveniences of display. The section is arranged as follows: §5.1 states the ground for choosing the axes, §5.2 states the axis of representation, §5.3 the axis of reach, §5.4 the reversibility dimension recorded alongside, §5.5 the four regions the axes define, and §5.6 states the exclusions.

5.1 The Ground for Choosing the Axes

A landscape may be organised on many principles, and the choice determines what the placement can establish.

The systems at issue might be sorted by physical medium, and the sorting would reproduce the domains by which governance is presently organised, so that a survey performed on it could exhibit no misfit between those domains and the systems. They might

be sorted by extent, and the sorting would place a watershed and an orbital shell far apart while saying nothing about how either is governed. They might be sorted by the severity of damage presently observed, and the sorting would place a system where its damage has been noticed, which §9 establishes to be a property of the observing arrangements.

The axes adopted in this paper are the two limitations by which the class is constituted. A system is placed by how much of it becomes representable to a governing party and by how much of it that party can alter by deliberate action. The choice follows from the companion agenda paper's constitution of the class, under which these two limitations, together with the crossing between them, are the conditions of the governing party.

The choice carries a consequence the paper accepts. A placement on these axes is a placement of a system with respect to a party, so a system occupies different positions for parties differently equipped, and §6.1 states the party with respect to which the placements are made.

5.2 The Axis of Representation

The first axis records how much of a system becomes representable to a governing party.

A system stands wide on this axis where its participants are enumerable, its couplings describable, and its condition estimable from records a party holds or can acquire. It stands narrow where the participants are not enumerated, where couplings are inferred from partial observation, and where the categories in which a description is framed are subject to revision by the system.

Two features of a system move it toward the narrow end and are recorded in the placements of Section 6. The first is the number of kinds of participant together with hierarchical structure among them, which is the characteristic by which the classification of §3.1 identifies complexity. The second is the duration over which observation has continued, since a condition estimated against natural variability requires a record long enough to establish a trend.

5.3 The Axis of Reach

The second axis records how much of a system a governing party can alter by deliberate action.

A system stands wide on this axis where a party can act on its participants directly, where the effects of an action are localised to what the action touches, and where an action may be undone by a further action. It stands narrow where a party acts on a small portion, where effects propagate to portions the party does not touch, and where the acting party is one among many with no coordination among them.

The axis is distinguished from the first in a respect the companion papers establish and which the placement of Section 6 exhibits. Reach and representation vary independently, so a system may be described in detail and reached hardly at all, and a system may be altered extensively and described poorly.

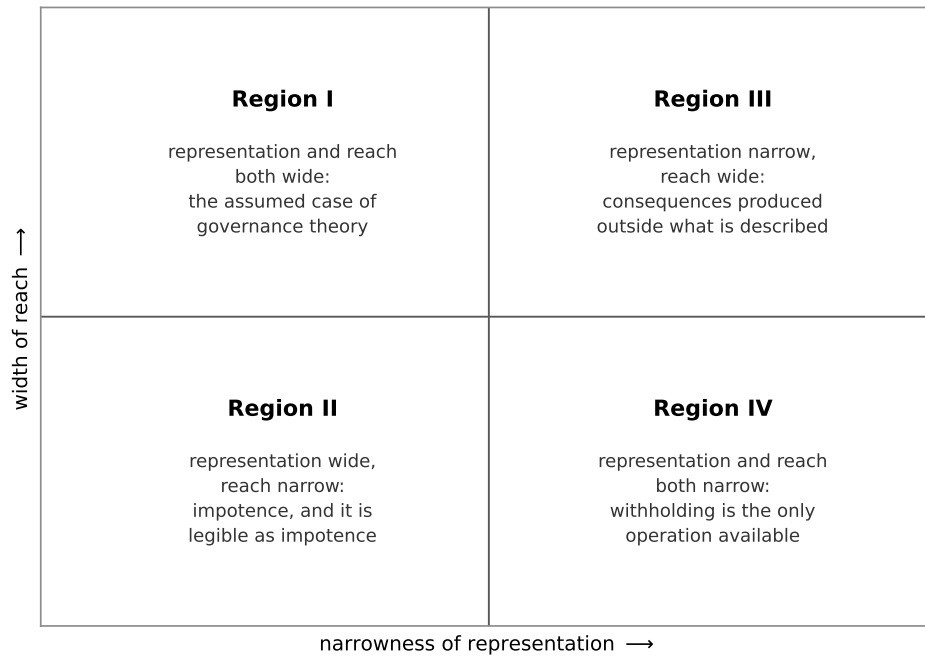


Figure 1: The four regions defined by the axes of representation and reach, with the characteristic condition of each. Region III is the regime the companion papers identify as most dangerous; Region IV is the regime in which the operation of withholding is the only one available.

5.4 The Dimension Recorded Alongside

A third quantity is recorded for each system without occupying an axis, and the ground for keeping it off the axes is stated below.

The reversibility horizon of a system is the period over which a foreclosure produced within it admits reversal by means available to any party. A foreclosure in a system whose horizon is short may be undone within a period the affected participants traverse; a foreclosure in a system whose horizon runs to centuries stands for practical purposes permanently.

The quantity is recorded separately because it governs what follows from a placement in place of where the placement falls. Two systems adjacent on both axes may differ entirely in what a foreclosure within them costs, and the companion paper on justificatory burden turns on exactly that difference.

5.5 The Regions the Axes Define

The axes define four regions, and each carries a characteristic condition that the survey of Section 6 uses to group its placements.

Region I holds systems represented widely and reached widely. It is the region for which governance theory has developed, and its questions are the questions of authority, constraint and accountability among parties who can be addressed.

Region II holds systems represented widely and reached narrowly. Its characteristic condition is impotence: a party states what is happening and states that it cannot act. The

condition is severe and it is legible, and a party in this region requires capacity in place of a criterion.

Region III holds systems represented narrowly and reached widely. Its characteristic condition is the production of consequences a party holds no description of, and the condition is illegible in the specific sense that the absence of an observed effect carries no evidential weight. The companion papers identify this region as the one their results principally address.

Region IV holds systems represented narrowly and reached narrowly. Its characteristic condition is that most governance operations are unavailable: a party cannot enable what it cannot reach, cannot constrain what it cannot describe, and cannot prevent what it does not act upon. What remains available is the withholding of the party's own courses, which is the operation the companion paper on the four operations finds to lack a doctrine.

The last observation is the section's principal finding and it was not anticipated in the choice of axes. The operation for which no doctrine exists is the operation that remains available exactly where the other three fail, and §10 states the consequence for how the companion results are distributed across the landscape.

5.6 Exclusions from the Axes

Three matters lie outside the construction, concerning respectively measurement, the bearer of the properties recorded, and the properties left unrecorded.

The first is that the axes carry no metric. Each records a comparative property, the placements of Section 6 state that one system stands wider than another and state no quantity, and §11.2 argues the declination of a metric.

The second is that they record properties of a relation between a system and a party, and no property of a system alone. Definition 4.1 makes the same move for heterogeneity, and the two are consistent in that respect.

The third is that they record neither the quality of an arrangement nor the severity of damage within a system. Section 7 overlays the arrangements and §9 treats where damage has been observed, and neither bears on where a system is placed.

6 The Systems Placed

This section states the party with respect to which the placements are made, places eleven systems on the axes of Section 5, records the reversibility horizon of each, and states the standing of the placements. The placements are displayed in Figure 2 and are comparative judgements offered for contest. Its role in the paper is the survey's substance: the placements made in this section are the material on which every finding of Sections 8 to 10 rests. The section is arranged as follows: §6.1 states the party with respect to which the placements are made and records the exclusion this entails, §6.2 places the systems standing wide on both axes, §6.3 the systems standing narrow on representation, §6.4 the systems standing narrow on both axes, and §6.5 states the standing of the placements.

6.1 The Party with Respect to Which the Placements Are Made

Section 5 established that a placement on these axes is a placement of a system with respect to a party. The reference party must therefore be stated.

The reference party is a state holding developed scientific and administrative capacity, acting through its own institutions and through the multilateral arrangements to which it is party. The choice is made because such a party is the one the arrangements of Section 7 address, and because it is the party for which representation and reach are widest, so that a system placed narrowly for this party is placed narrowly for every party.

Two consequences follow from the choice of reference party, the first concerning parties less equipped and the second concerning the standing of the landscape as a whole.

The first is that a system's placement moves toward the narrow end of both axes for a party less equipped, and the companion paper on the determination of system state establishes that the movement is systematic in one respect: observational capacity is acquired through use, so a party entering a system later stands narrower on the axis of representation permanently.

The second is that the landscape as drawn is the most favourable one available. Where it exhibits a system as poorly represented or poorly reached, no party stands better.

One class of observation is excluded by the choice, and the exclusion is recorded here in the terms Section 12 carries forward. A party resident within a system may hold observation sustained over periods exceeding any institutional record, and Wynne [13] establishes that such observation may carry standing that institutional assessment fails to receive. A placement made with respect to the party of this subsection records what that party's instruments and records reach, and a system placed narrowly here may be well observed by parties whose observation the placement does not count.

6.2 The Systems Placed toward the Wide End of Both Axes

Four systems stand toward the wide end of representation and of reach, and are treated in order of decreasing reversibility horizon.

A watershed within a single jurisdiction is enumerable in its principal participants, describable in its couplings, monitorable by instruments a party may deploy at will, and alterable by works the party may construct and remove. Its reversibility horizon runs in years for water quality and in decades for channel form.

A metropolitan airshed stands similarly, and its horizon is the shortest of any system surveyed, since the atmosphere above a city clears within days of a change in what is emitted into it.

A managed temperate forest stands slightly narrower on representation, since its soil and microbial participants are not enumerated, and its horizon runs in decades for stand composition and in centuries where old growth is at issue.

A night sky over a settled region stands wide on both axes, and its position bears directly on the finding of Section 7. Sky brightness is measurable by inexpensive instruments and has been mapped globally [2], the sources are enumerable and are almost entirely artificial, and

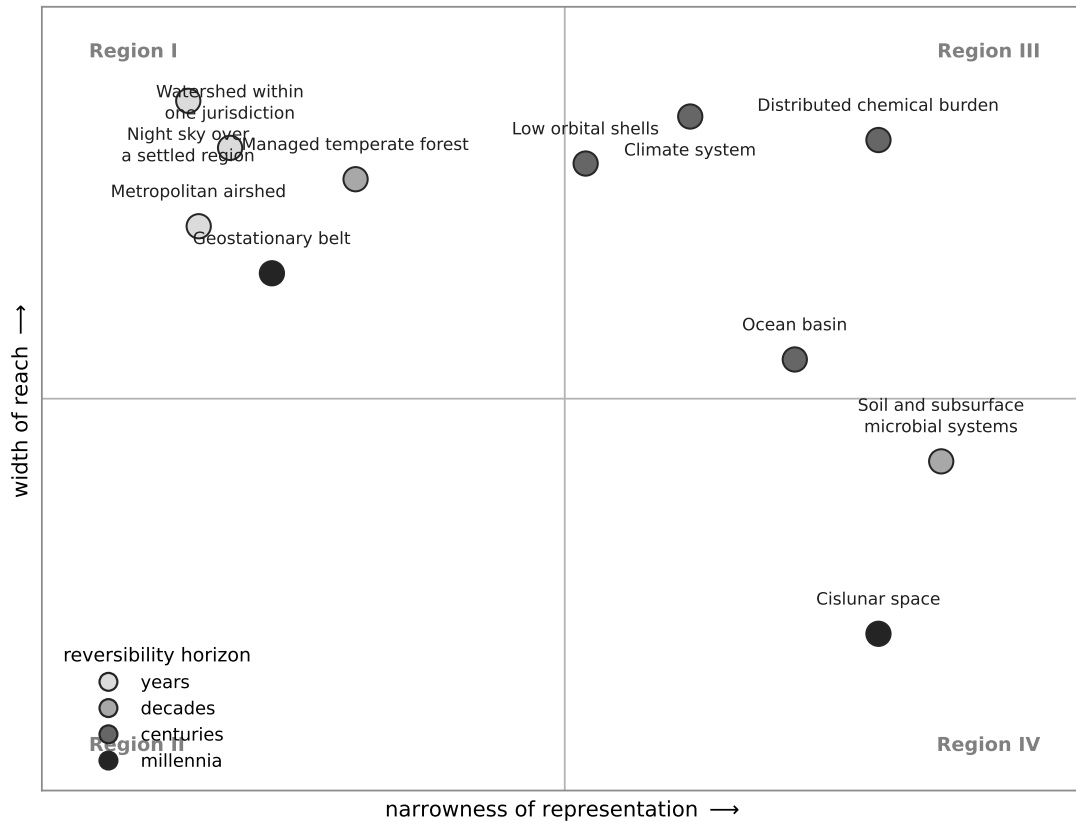


Figure 2: Eleven systems placed on the axes of representation and reach, with shading recording the order of magnitude of the reversibility horizon. Positions are comparative judgements with respect to the party of §6.1 and no quantity is measured.

the reach of a party over them is nearly complete, since illumination is produced by fixtures the party licenses and may require to be shielded, redirected or extinguished. Its horizon runs in years, since a sky darkens when the lighting changes. Among all systems surveyed it is the one most favourably placed on every dimension, and Section 7 records what governs it.

6.3 The Systems Placed toward the Narrow End of Representation

Five systems stand narrow on representation while remaining widely reached, occupying the region Section 5 identifies as most dangerous.

The low orbital shells are tracked for objects above a size threshold and are untracked below it, so that the population governing the collision rate is partly outside what any catalogue holds. The reach of a party is wide, since a launch places objects at a chosen altitude. The horizon runs in centuries at the altitudes carrying the densest traffic.

An ocean basin is described at its surface and sparsely at depth, its principal participants are not enumerated, and the reach of a party extends through fishing, shipping, discharge and extraction without extending to most of what those activities affect. The horizon runs in centuries for deep circulation and for the recovery of long-lived populations.

The climate system is heavily modelled in aggregate and poorly resolved at the scales at

which thresholds are approached, which places it narrow on representation for the purposes a determination of proximity requires. Its reach is the widest of any system surveyed, since every party alters it continuously. The horizon runs in centuries and beyond.

The distributed chemical burden stands narrowest on representation among the systems surveyed. The substances in circulation number in the tens of thousands, their interactions are largely undescribed, and the participants affected are not enumerated. The reach is wide, since production places substances into circulation directly. The horizon runs in centuries for persistent compounds.

Soil and subsurface microbial systems stand narrow on representation and moderate on reach, since a party alters them through land use without acting on their participants. The horizon runs in decades for structure and longer for composition.

6.4 The Systems Placed toward the Narrow End of Both Axes

Two systems stand narrow on both axes, and their positions differ in kind despite the shared placement.

Cislunar space is sparsely observed, few parties reach it, and both conditions are presently changing. Its horizon runs in millennia, since nothing removes what is placed there.

The geostationary belt stands as the counterpart within this group, and its placement exhibits the point of §5.4 in its clearest form. It is among the best represented of the systems surveyed, since its occupants are few, catalogued and coordinated, and its reach is moderate, since access requires capability held by a limited set of parties. Its horizon is nonetheless among the longest, since no drag removes an object from that altitude. The belt accordingly exhibits the point of §5.4 in its clearest form: a system may be well placed on both axes and carry a horizon that makes any foreclosure within it permanent.

6.5 The Standing of the Placements

Three matters bear on how the placements are to be read, concerning respectively their standing as judgements, their currency, and their completeness.

The first is that each placement is a comparative judgement and none rests on a measurement. A reader holding that the climate system is better represented than the ocean basin, or that soil systems are more widely reached than stated, disputes a judgement the paper offers for dispute, and the findings of Sections 8 to 10 survive the relocation of any single system.

The second is that the placements are stated for the present. Cislunar space is moving on both axes as capability develops, low orbital representation improves as sensors are added, and the chemical burden narrows on representation as the number of substances grows.

The third is that the set is incomplete. Freshwater aquifers, ice sheets, the deep subsurface, the radio spectrum and the biosphere considered whole exhibit the characteristics of §3.1 and are omitted, and §12.2 records the omissions and their likely positions.

7 The Arrangements Overlaid

This section records what presently governs each system placed in Section 6. It states the form of the record, sets out the arrangements by region, and establishes the finding the overlay produces, which is that the density of governance stands in no regular relation to position on the axes. The arrangements are assembled in Table 1. Its role in the paper is to complete the landscape by recording what presently governs each region, and the finding it produces is the question Section 9 answers. The section is arranged as follows: §7.1 states the form of the record, §7.2 to §7.4 set out the arrangements by region, and §7.5 states Finding 7.1.

7.1 The Form of the Record

An arrangement is recorded by its instrument, by whether the instrument binds, and by the party to whom it is addressed. Effectiveness is outside the record, following the restriction at §2.2.

Density is used comparatively throughout and denotes the extent to which a system is addressed by instruments that bind some party to something determinate. A system addressed by a binding treaty with reporting obligations and a domestic permitting regime is dense; a system addressed by voluntary designation and advisory standards is sparse; a system addressed by neither is unoccupied.

7.2 The Arrangements Addressing the Systems Placed Widely

Three of the four systems placed toward the wide end of both axes are densely governed.

A watershed within one jurisdiction is addressed by abstraction and discharge permitting, by quality standards, and by assessment obligations attaching to works within it. A metropolitan airshed is addressed by emission limits and ambient standards with monitoring obligations attached. A managed forest is addressed by forestry statute, by designation, and by harvest licensing.

The fourth is not, and the divergence is the finding of §7.5. A night sky over a settled region is addressed by local lighting ordinances where a municipality has adopted them, by voluntary designation where a body has certified an area [1], and by advisory standards addressed to satellite operators. No instrument binds a party to a sky brightness, and the system most favourably placed on every dimension surveyed is among the two most sparsely governed.

7.3 The Arrangements Addressing the Systems Placed Narrowly on Representation

The five systems standing narrow on representation are governed with a range of densities that bears no relation to their placement.

The climate system is the most densely governed system in the survey. A framework convention [12], an agreement within it with nationally determined contributions and a periodic stocktake [8], domestic pricing and transition statutes, and three recent advisory

Table 1: The systems of Section 6 against the arrangements presently addressing them, with the comparative density of those arrangements.

System	Principal arrangements	Density	Region
Watershed within one jurisdiction	Abstraction and discharge permitting, quality standards, impact assessment	Dense	I
Metropolitan airshed	Emission limits, ambient standards, monitoring obligations	Dense	I
Managed temperate forest	Forestry statute, protected designation, harvest licensing	Dense	I
Climate system	Framework convention, Paris Agreement with contributions and stocktake, domestic pricing and transition statutes, recent advisory opinions	Densest	III
Ocean basin	Law of the Sea, regional fisheries bodies, dumping conventions, the agreement on areas beyond national jurisdiction	Dense	III
Distributed chemical burden	Persistent organic pollutant convention, registration regimes, the global framework on chemicals	Moderate	III
Low orbital shells	Registration and liability conventions, mitigation guidelines, sustainability guidelines, national licensing	Moderate, largely non-binding	III
Geostationary belt	Slot and frequency coordination, disposal requirements	Moderate	IV boundary
Soil and subsurface microbial systems	Contamination statutes addressed to substances; the systems themselves unaddressed	Sparse	III
Night sky over a settled region	Local lighting ordinances, voluntary designation, advisory standards for satellite operators	Sparse	I
Cislunar space	Non-appropriation and due regard; no instrument addressed to the region	Unoccupied	IV

opinions all address it. It stands among the narrowest on representation for the purpose a proximity determination requires, and among the widest on reach.

An ocean basin is densely governed by a convention of general application [11], by regional fisheries bodies, by dumping conventions, and by a recent agreement addressed to areas beyond national jurisdiction.

The distributed chemical burden is moderately governed, by a convention addressed to a listed class of persistent substances [9], by registration regimes conditioning market access, and by a recently adopted global framework.

The low orbital shells are moderately governed and largely by instruments that do not bind. Registration and liability conventions bind; mitigation guidelines and sustainability

guidelines do not; national licensing binds the licensee.

Soil and subsurface microbial systems are sparsely governed, and the sparseness takes a particular form. Contamination statutes address substances entering the soil and the systems themselves are addressed by no instrument, so that what is governed is an input and what is at issue is a set of participants.

7.4 The Arrangements Addressing the Systems Placed Narrowly on Both Axes

Cislunar space is unoccupied. The non-appropriation provision and the obligation of due regard [10] apply to it as to any region beyond national jurisdiction, and no instrument addresses the region as such.

The geostationary belt stands otherwise, and its arrangements are the oldest addressed to any orbital region. Slot and frequency coordination under the radio regulations [5] has operated for decades and disposal requirements attach to occupants at end of life.

7.5 The Finding the Overlay Produces

Finding 7.1 (Density and placement). The comparative density of the arrangements addressing a system stands in no regular relation to the system's position on either axis. The most densely governed system surveyed stands among the narrowest on representation and the widest on reach; the system most favourably placed on both axes and carrying the shortest reversibility horizon is among the most sparsely governed.

Three consequences follow from Finding 7.1, and Sections 8 and 9 develop the first and the pair that follow it respectively.

The first is that the tractability of a system predicts neither that it is governed nor that it is not. A party seeking to account for why an arrangement exists where it does must appeal to something other than the two limitations, and §9 argues that the something is the visibility of damage.

The second, which follows from the first in one direction, is that the absence of an arrangement is no evidence that governing a system would be difficult. The night sky is the standing instance: it is governed sparsely and it is the system a party could govern most readily.

The third, which follows in the other direction, is that the presence of a dense arrangement is no evidence that a system is tractable. The climate system is the standing instance in the other direction, and the companion papers establish that the instruments addressing it operate under exactly the limitations its placement records.

8 The Clustering of the Systems and the Misfit It Exhibits

This section states what the placements of Section 6 exhibit when read across the domains by which governance is presently organised. It states the form of the claim, sets out the clusters, distinguishes the misfit it identifies from the one already established in the literature, and

states what the clustering withholds. Its role in the paper is the first of the three findings: the clustering establishes that the systems group by their constitutive limitations and not by the domains under which governance is organised. The section is arranged as follows: §8.1 states the form of the claim, §8.2 and §8.3 set out the two clusters, §8.4 treats the pair adjacent on the axes and distant in domain, §8.5 distinguishes the misfit identified from the boundary mismatch the literature has established, and §8.6 states the exclusions.

8.1 The Form of the Claim

Governance of the systems surveyed is organised by medium. Water, air, land, living resources, chemicals and outer space each carry their own instruments, their own administering bodies, their own bodies of doctrine and their own scholarly literatures.

The axes of Section 5 are stated over the constitutive limitations and take no account of medium. A claim of misfit follows where systems adjacent on the axes fall in different media, and where systems within one medium fall far apart on the axes.

The claim is established by exhibition and is qualitative throughout, as §6.5 records for the placements it rests on.

8.2 The Cluster Standing Narrow on Representation

Five systems occupy the region of narrow representation with wide reach, and they fall in five media.

The climate system, an ocean basin, the distributed chemical burden, the low orbital shells and the subsurface microbial systems are adjacent in the respect the axes record. Each is altered extensively by parties that describe a small portion of it, and each accordingly presents the difficulty that an absence of observed consequence carries no evidential weight.

They are governed by five separate arrangements with no instrument in common. A framework convention with contributions addresses the first; a convention of general application with regional bodies addresses the second; a listing convention with registration regimes addresses the third; registration and liability conventions with non-binding guidelines address the fourth; and contamination statutes addressed to inputs address the fifth.

No route exists by which an instrument developed for one is available to another. The doctrinal literatures are separate, the administering bodies are separate, and a party facing the difficulty in one medium consults the tradition of that medium, which has met the difficulty in that medium alone.

8.3 The Cluster Standing Wide on Both Axes

Four systems occupy the region of wide representation with wide reach, and they are governed at densities that differ by the largest margin in the survey.

A watershed, an airshed and a managed forest are densely governed and their instruments are of one general kind: a permitting regime addressed to activities, standards attached to a measurable quantity, and an assessment obligation attaching to works.

A night sky is governed sparsely and by instruments of another kind entirely. The permitting regime, the standard and the assessment obligation are all available for it, since illumination is licensed, sky brightness is measurable and the works producing it are constructed. None is generally applied.

The cluster accordingly exhibits an instrument set developed within one region of the landscape and left unapplied to a system standing in the same region. The transfer that Section 7 finds absent is not a transfer across a difficulty; it is a transfer across a medium.

8.4 The Pair Adjacent on the Axes and Distant in Domain

One pair among the systems surveyed states the misfit in its sharpest form, being adjacent on the axes and maximally distant in domain.

The low orbital shells and the distributed chemical burden stand near one another on both axes and carry reversibility horizons of the same order. Each carries a threshold above which accumulation becomes self-sustaining [6], and each accumulates through the independent decisions of many parties, each carries a threshold above which the accumulation becomes self-sustaining or self-perpetuating, each is observed by instruments held disproportionately by the parties that use it, and in each the population governing the outcome is partly below the threshold of detection.

The two are maximally distant in domain. One is governed through space law and the other through chemicals regulation; the bodies, the instruments, the doctrines and the literatures share nothing.

A party facing either has met the other's problem, and holds no route by which the meeting is legible as such.

8.5 The Misfit Distinguished from the One Already Established

The environmental governance literature has established a problem of fit, under which an institution fails where its spatial and temporal boundaries diverge from those of the system it governs [14].

The misfit stated in this section is of a different kind and the two are compatible. The established problem concerns a mismatch between the boundaries of an institution and the boundaries of a system. The present one concerns a mismatch between the principle on which institutions are organised, which is medium, and the principle on which the difficulty is organised, which is the pair of constitutive limitations.

The consequence differs accordingly. A boundary mismatch is repaired by redrawing a boundary, and the literature has proposed such redrawings. A mismatch of organising principles is repaired by a route along which an instrument developed for one medium becomes available to a system in another that stands in the same region, and no such route is proposed in this paper, for the reason given at §11.4.

8.6 Exclusions from the Clustering Claim

Three matters lie outside the claim, concerning respectively its evidential base, its reach onto particular instruments, and its historical dimension.

The first is that the clustering rests on the placements and inherits their standing. A reader relocating a system relocates it within the clustering, and §6.5 records that the findings survive the relocation of any single system while stating no bound on how many.

The second is that the claim is confined to the availability of instruments across media; whether a given instrument would work in a given system is a further question. An instrument developed for an airshed may fail in an orbital shell for reasons the present axes do not record.

The third is that the claim is confined to the present organisation of governance; how that organisation arose is a historical question outside it. Media are the natural units for many purposes, and the paper establishes only that they are not the units in which this class of difficulty is organised.

9 The Unoccupied Regions and the Condition Governing Their Occupation

This section answers the question Finding 7.1 leaves. It states the hypothesis that governance density tracks the visibility of damage, tests the hypothesis against the survey, records the case that appears to refute it, establishes that this case supplies the mechanism in place of a refutation, and states the consequence for the regions the arrangements leave unoccupied. Its role in the paper is the second of the three findings: the constructed-visibility account explains where the arrangements stand and yields the consequence for the regions they leave empty. The section is arranged as follows: §9.1 states the question Finding 7.1 leaves, §9.2 states the hypothesis, §9.3 records the case appearing to refute it, §9.4 establishes the circularity that case exhibits, §9.5 states the consequence for the unoccupied regions, and §9.6 states the exclusions.

9.1 The Question Finding 7.1 Leaves

Finding 7.1 establishes that density stands in no regular relation to placement. A party seeking to account for where the arrangements stand must therefore appeal to something other than the two limitations.

Two candidate accounts are set aside before the hypothesis is stated. Density does not track the stakes, since the systems carrying the longest reversibility horizons include both the most densely governed and the entirely unoccupied. Density does not track the extent of use, since the night sky is used intensively by every party and is governed sparsely, while the geostationary belt is used by few and is governed by the oldest orbital arrangement in existence.

9.2 The Hypothesis

The account this section examines is that density tracks the visibility of damage, in the sense that an arrangement is adopted where a party has been shown a loss it can attribute.

The hypothesis has immediate support from the densely governed systems. Watershed and airshed regimes followed episodes in which a loss was displayed within a period a party could observe and attributed to a source a party could name. Ocean arrangements followed the collapse of identified fisheries and the discharge of identified cargoes. Chemicals conventions followed the accumulation of identified substances in identified populations.

It has support from the sparsely governed systems in the other direction. The loss produced by sky brightening is diffuse, it accrues to populations that render no account of it and to observers whose difficulty is registered within one profession, and no episode displays it. The loss produced within subsurface microbial systems is not displayed at all, since the participants are not enumerated and their condition is not monitored.

9.3 The Case Appearing to Refute the Hypothesis

The climate system refutes the hypothesis of §9.2 as stated. Its damage is diffuse, it accrues over periods exceeding those a party observes directly, its attribution to a source was contested for decades, and it is nonetheless the most densely governed system in the survey.

The refutation supplies the amendment the hypothesis requires, and the amendment concerns the source of visibility in place of its role.

The visibility of climate damage was constructed. An observational and assessment apparatus, of which the intergovernmental assessment panel is the institutional centre [4], was built over decades, at great expense, expressly to render a diffuse and slow loss displayable and attributable to sources a party could name. The density of the arrangement followed the construction of the visibility and did not precede it.

Finding 9.1 (Density and constructed visibility). The comparative density of the arrangements addressing a system tracks the visibility of loss within it, and the visibility of loss is a property of the observational arrangements addressed to the system in place of a property of the loss. A system whose losses are displayed by an apparatus built for the purpose is governed densely whether or not its losses would otherwise be noticed; a system to which no such apparatus is addressed is governed sparsely whether or not its losses are severe.

9.4 The Circularity the Finding Exhibits

Finding 9.1 stands in a determinate relation to a result of the companion paper on the determination of system state, and the two together exhibit a circularity.

An arrangement governing a system requires that losses within it be displayed. Their display requires an observational apparatus. An apparatus requires instruments, records and observation sustained over a period, and the companion paper establishes that the most valuable of these cannot be acquired by present expenditure and is acquired in the course of using the system.

The occupation of a region of the landscape therefore requires a prior investment in observing it, the investment is made by parties that use the system, and the use is what the eventual arrangement will constrain. A region unused is unobserved, a region unobserved

displays no loss, and a region displaying no loss attracts no arrangement.

The circularity is broken in the cases where it has been broken by an apparatus built ahead of the arrangement and independently of the parties using the system. The climate case is the principal instance, and the companion paper's condition concerning a public observational record of sufficient duration is the general statement of what such an apparatus supplies.

9.5 The Consequence for the Unoccupied Regions

Three consequences follow from Finding 9.1 for the regions the arrangements leave unoccupied, two of them negative and the third stating the order in which occupation proceeds.

The first is that an unoccupied region carries no presumption that its systems are unimportant. Finding 9.1 establishes that occupation follows displayed loss, and displayed loss follows an apparatus, so that a region may be unoccupied because no party has built the apparatus that would display what occurs there.

The second is that an unoccupied region carries no presumption that its systems are difficult. Finding 7.1 establishes the point directly and the night sky exhibits it, since the apparatus required there is inexpensive and the instruments of governance are already in the hands of the parties that would apply them.

The third is that the order in which regions become occupied is fixed by the order in which observational apparatus is built, and that order is fixed by the order in which parties began to use the systems. Cislunar space stands unoccupied now for the reason low orbit stood unoccupied within living memory.

9.6 Exclusions from the Account

Three matters lie outside this section, concerning respectively the adequacy of arrangements, the historical record, and the normative question the finding raises.

The first is that the account concerns the density of arrangements and concerns their adequacy in no respect. A densely governed system may be governed badly and §2.2 restricts the survey accordingly.

The second is that it offers a condition, the history being a further undertaking. Whether each dense arrangement in fact followed a displayed loss is a historical question the paper states as a pattern, its case-by-case establishment remains to be done, and §12.1 records the boundary.

The third is that the account establishes that visibility is constructed, while establishing nothing about who should construct it. The companion papers state what an arrangement securing such construction would have to satisfy, and §11.4 states why no proposal is offered in this paper.

10 The Location of the Companion Results on the Landscape

This section states the region of the landscape over which each companion result holds. It states what locating a result consists in, treats the four in turn, states the finding the locations jointly produce, and records the regions no result presently addresses. Its role in the paper is the third of the three findings and the paper's principal service to the series: each companion result is located on the landscape, and the locations establish that the results hold over determinate and differing regions. The section is arranged as follows: §10.1 states what locating a result consists in, §10.2 to §10.4 locate the three results in turn, §10.5 states the finding the locations jointly produce, and §10.6 records the regions no result addresses.

10.1 The Form of the Location

A result is located by the conditions its argument uses. Where an argument uses a condition that a system fails to satisfy, the result is unavailable for that system, and the region over which the result holds is the region within which its conditions obtain.

The locating serves two purposes. It states for a party facing a particular system which of the results bear on it, and it exhibits which regions of the landscape the series has addressed and which it has left.

10.2 The Result on Justificatory Burden

The criterion allocating the burden of justification where a course would irreversibly foreclose the generative capacity of a trajectory other than the acting party's own uses two conditions.

It uses narrow representation, since the criterion is constructed to be stable on information a party holds at the point of decision and would be unnecessary where a party could survey what it forecloses. It uses a reversibility horizon exceeding the period the affected participants traverse, since the criterion fires on irreversibility and stands silent otherwise.

The result accordingly holds across Regions III and IV for systems whose horizons are long, and it stands silent over Region I and over the short-horizon systems anywhere. A watershed and an airshed fall outside it almost entirely. The night sky falls outside it on the horizon condition, notwithstanding the sparseness of what governs the sky, and §10.6 records the consequence.

10.3 The Result on the Determination of System State

The result establishing that the capacity to determine a system's state is acquired through use of it, so that the party best equipped to determine is the party a determination favours, uses three conditions.

It uses narrow representation, since a determination made on complete information supports no convergence. It uses critical behaviour, since the determination at issue concerns proximity to a value at which the dynamics change. It uses a plurality of parties whose prior use is unequal.

The result holds over Region III throughout and over the portion of Region IV in which several parties act. It is strongest where the observational instruments are held by few, which the survey finds in the low orbital shells and in the deep portions of an ocean basin, and it takes the inverted form recorded in the companion paper where the record is held by a party external to the system, which the survey finds in the ecological cases.

10.4 The Result on the Four Operations

The result establishing that existing schemes hold no doctrine of withholding a possibility while retaining its availability uses one condition and holds more widely than the others.

It uses only that a possibility withheld remains available, which is a condition on the reversibility horizon and on the physical character of the withholding in place of a condition on representation or reach.

The result accordingly holds across the whole landscape, and §5.5 establishes that its subject matter becomes the sole available operation in Region IV. The two together produce the finding of §10.5.

10.5 The Finding the Locations Produce

Finding 10.1 (Coverage of the landscape by the companion results). The results of the series are distributed unevenly across the landscape and their distribution is the reverse of the distribution of the arrangements. The arrangements are dense in Region I and in the visible portions of Region III, and the results hold over Regions III and IV. The region in which the fewest governance operations remain available is the region the arrangements occupy least and the results address most.

Two consequences follow from Finding 10.1, the first concerning what the series addresses and the second concerning what it leaves to others.

The first is that the series addresses the region a party is least equipped to act in, and addresses it with results whose principal content is a constraint on the party's own conduct. The distribution is consistent with §5.5, under which the withholding of a party's own courses is what remains available where representation and reach both fail, so that the results concentrate where the operations do.

The second is that the coverage of Region I, in which most governing presently occurs, is the thinnest the series provides. A party administering a watershed obtains from the series a taxonomy of operations and a finding about the doctrine of one of them, and obtains no criterion, since the criterion fires on a condition a watershed does not satisfy.

10.6 The Regions the Series Leaves

Three portions of the landscape are addressed by no result of the series, and each is recorded here with the ground on which the omission stands.

The first holds the systems standing wide on both axes with short reversibility horizons,

which are addressed by none of the results and are governed densely. The omission is appropriate, since the conditions on which the results turn are conditions such systems fail.

The second holds the systems standing wide on both axes with short horizons and sparse arrangements, which are likewise addressed by none of the results and are governed sparsely. The night sky is the case, it is the case the survey finds most anomalous, and no result of the series reaches it. What reaches it is Finding 9.1, which states why it is ungoverned, and §12.3 records that a finding about why a system is ungoverned supplies no criterion for governing it.

The third holds the systems standing narrow on both axes with a single acting party, which are addressed by the first result and by neither of the others, since the second requires a plurality of parties and the third requires an existing scheme to hold or lack a doctrine. Cislunar space presently satisfies this description and will cease to as more parties reach it.

11 Positions Declined and the Arguments for Declining Them

This section argues the four declinations announced at §2.4. Each position is stated at the strength its proponents would give it, the ground for declining it is derived from a result established in Sections 5 to 10, and the cost is stated. Its role in the paper is to discharge the four announcements of §2.4 with arguments, so that each declination stands on a stated result in place of on preference. The section is arranged as follows: §11.1 declines completeness, §11.2 declines a metric, §11.3 declines an assessment of the tradition drawn on, and §11.4 declines a proposal for the unoccupied regions.

11.1 The Declination of Completeness

The position declined holds that a synoptic survey should be exhaustive over the systems satisfying its classification, and that a partial survey supports no finding about the whole.

The ground for declining it is the form of the findings. Finding 7.1 asserts that density stands in no regular relation to placement, and a single pair standing far apart on placement and close on density establishes it. Finding 9.1 asserts a condition governing occupation and is supported by the pattern across the systems surveyed together with the constructed case that supplies its mechanism. Neither requires that the survey be closed.

The cost is that no claim about proportions is available. The paper cannot state how much of the landscape stands unoccupied, how many systems fall in each region, or whether the anomalies it exhibits are frequent.

11.2 The Declination of a Metric

The position declined holds that axes admitting no measurement are not axes, and that a survey placing systems by judgement has produced an illustration in place of a finding.

The ground for declining it is derived from §4.3 and from the companion paper on justificatory burden. A metric on the axis of representation would require a measure over what a system contains, so that the represented portion could be expressed as a fraction of it.

Definition 4.1 states that no common measure over the participants of these fields is available to the parties governing them, and a metric supplied notwithstanding would be a measure the paper has argued no party holds.

A second ground is that a metric would license comparisons the judgements do not support, and the findings require only ordinal comparisons of the kind the judgements supply.

The cost is that every placement is contestable and that no procedure exists for settling a contest. §12.1 records the consequence.

11.3 The Declination of an Assessment of the Tradition Drawn On

The position declined holds that the relation stated at §3.4 amounts to an assessment of the meta-synthesis programme, favourable or otherwise, and that a paper drawing its vocabulary from the tradition owes such an assessment.

The ground for declining it is the standing fixed at §3.2. The classification is drawn on as an inspiration and a vocabulary by a paper working in a different field, the relation stated at §3.4 is a difference between two questions and carries no judgment of the programme addressed to the first of them, and an assessment would require competence within systems science that a discussion in social science neither holds nor claims.

The cost is that the paper draws a vocabulary from a tradition whose methodology it leaves entirely unexamined, and a reader may hold that the two are not separable in the tradition's own presentation. §3.3 records that they are presented together, and the paper accepts that its use of the classification is partial in exactly this respect.

11.4 The Declination of a Proposal for the Unoccupied Regions

The position declined holds that a paper establishing which regions stand unoccupied should propose what would occupy them.

The ground for declining it is derived from Finding 9.1 together with §9.4. Occupation follows displayed loss, display follows an apparatus, and an apparatus requires a record of a duration that no present expenditure supplies. A proposal for an instrument would address the last stage of a sequence whose first stage is unmet, and its adoption would furnish an appearance of occupation.

A second ground is derived from the companion papers, each of which establishes a difficulty that an arrangement proposed now would inherit.

The cost of the four declinations taken together is the following. The paper establishes that the night sky is the system most readily governed and least governed, and the means by which the second condition would change remains for other work to supply.

12 The Limits of the Survey

This section states the limits of the survey in three classes and closes by stating the revision the paper requires of its companions. Its role in the paper is closing: it states what the survey has not established, so that the landscape is used at its warranted strength and no further. The section is arranged as follows: §12.1 states the limits of the placements and of the findings resting on them, §12.2 records the systems omitted, §12.3 states the findings the survey does not supply, and §12.4 states the revision the survey requires of its companions.

12.1 Limits of the Placements and of the Findings Resting on Them

Four limits attach to the survey as constructed, running from the standing of the individual placements to the standing of the findings that rest on them.

The first is that every placement is a comparative judgement and none rests on a measurement. §11.2 argues the declination of a metric and the cost is that a contest over a placement admits no procedure for settling it.

The second is that the findings inherit the placements. §6.5 records that they survive the relocation of any single system and states no bound on how many relocations they survive, and a reader relocating several would be entitled to ask for the bound.

The third is that the pattern asserted at §9.2, under which dense arrangements followed displayed losses, is stated as a pattern and is not established case by case. A historical treatment of each arrangement would be required and is not offered.

The fourth is that the record of the arrangements is stated as of the present and omits their trajectories. Several are recent, one class of them is a few years old, and a survey conducted differently would place them otherwise.

12.2 The Systems Omitted

The survey treats eleven systems and omits several exhibiting the same characteristics, and their likely positions are recorded so the omissions may be assessed.

Freshwater aquifers stand narrow on representation and moderate on reach, with horizons in centuries where recharge is slow. Ice sheets stand moderate on representation, narrow on reach, and carry the longest horizons of any terrestrial system. The deep subsurface stands narrowest of all on representation. The radio spectrum stands wide on both axes and is densely governed, and its inclusion would supply a second instance of the pattern the geostationary belt exhibits. The biosphere considered whole stands at the limit of both axes and its treatment would raise the individuation question the companion agenda paper records as open.

None of the omissions would relocate a system treated, and the first four would populate regions the survey exhibits as sparsely occupied.

12.3 The Findings the Survey Does Not Supply

Three questions the survey raises are left unanswered, and each is stated here so that a reader may take it up.

The first arises from Finding 9.1, which states why a system is ungoverned; a criterion for governing it is a further thing, and the finding leaves it to be built. The night sky exhibits the gap most clearly: the survey establishes that it is the system most readily governed and least governed, and the companion results do not reach it, since its reversibility horizon fails the condition on which the criterion fires.

The second arises from the clustering of §8, which identifies a route that does not exist, along which an instrument developed for a system in one medium would become available to a system in another standing in the same region. Whether such a route is constructible is not addressed.

The third arises from the exclusion recorded at §6.1, which the survey does not repair. Observation held by resident parties is outside what the placements count, a landscape drawn with respect to such a party would place several systems otherwise, and no such landscape is drawn in this paper.

The circularity of §9.4 is exhibited and is not broken. One case in which it has been broken is recorded, the companion paper states the condition such a breaking satisfies, and the conditions under which a party would undertake it are not stated.

12.4 The Revision the Survey Requires of Its Companions

Section 4 supplies a definition that the companion papers presuppose and do not state, and two consequences follow for them.

Where a companion paper describes a field as heterogeneous, the description is to be read as Definition 4.1 states it, and the papers have not been revised to say so.

The companion agenda paper groups heterogeneity among the conditions of the field. Under Definition 4.1 the grouping is wrong and the condition belongs among the conditions of the relation, and §4.4 states what the relocation improves and what it costs.

References

- [1] DarkSky International. *International Dark Sky Places Program*. Programme documentation and designation criteria, accessed August 2026.
- [2] Falchi, Fabio, Pierantonio Cinzano, Dan Duriscoe, Christopher C. M. Kyba, Christopher D. Elvidge, Kimberly Baugh, Boris A. Portnov, Nataliya A. Rybnikova, and Riccardo Furgoni. "The New World Atlas of Artificial Night Sky Brightness." *Science Advances* 2, no. 6 (2016): e1600377.
- [3] Gu Jifa and Tang Xijin. "Meta-synthesis and Knowledge Science." *Systems Engineering: Theory and Practice* 22, no. 10 (2002): 2–7. In Chinese.

- [4] Intergovernmental Panel on Climate Change. Established 1988 by the World Meteorological Organization and the United Nations Environment Programme; endorsed by UN General Assembly Resolution 43/53 of 6 December 1988.
- [5] International Telecommunication Union. *Radio Regulations*. Geneva: ITU, edition of 2024.
- [6] Kessler, Donald J., and Burton G. Cour-Palais. "Collision Frequency of Artificial Satellites: The Creation of a Debris Belt." *Journal of Geophysical Research* 83, no. A6 (1978): 2637–2646.
- [7] Qian Xuesen, Yu Jingyuan, and Dai Ruwei. "A New Discipline of Science: The Study of Open Complex Giant Systems and Its Methodology." *Ziran Zazhi* [Chinese Journal of Nature] 13, no. 1 (1990): 3–10. In Chinese.
- [8] Paris Agreement, adopted 12 December 2015, entered into force 4 November 2016.
- [9] Stockholm Convention on Persistent Organic Pollutants, 2256 UNTS 119, adopted 22 May 2001, entered into force 17 May 2004.
- [10] Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, 610 UNTS 205, opened for signature 27 January 1967.
- [11] United Nations Convention on the Law of the Sea, 1833 UNTS 3, opened for signature 10 December 1982, entered into force 16 November 1994.
- [12] United Nations Framework Convention on Climate Change, 1771 UNTS 107, opened for signature 4 June 1992, entered into force 21 March 1994.
- [13] Wynne, Brian. "Misunderstood Misunderstanding: Social Identities and Public Uptake of Science." *Public Understanding of Science* 1, no. 3 (1992): 281–304.
- [14] Young, Oran R. *The Institutional Dimensions of Environmental Change: Fit, Interplay, and Scale*. Cambridge, MA: MIT Press, 2002.