A PRINCIPLES-BASED ETHICAL ASSURANCE ARGUMENT PATTERN FOR AI AND AUTONOMOUS SYSTEMS

Zoë Porter, Ibrahim Habli, John McDermid

ABSTRACT

An assurance case presents a clear and defensible argument, supported by evidence, that a system will operate as intended in a particular context. Typically, an assurance case presents an argument that a system will be acceptably safe in its intended context. One emerging proposal within the Trustworthy AI research community is to extend and apply this methodology to provide assurance that the use of an AI system or an autonomous system (AI/AS) will be acceptably ethical in a particular context. In this paper, we advance this proposal further. We do so by presenting a principles-based ethical assurance (PBEA) argument pattern for AI/AS. The PBEA argument pattern offers a framework for reasoning about the overall ethical acceptability of the use of a given AI/AS and it could be an early prototype template for specific ethical assurance cases. The four core ethical principles that form the basis of the PBEA argument pattern are: justice; beneficence; non-maleficence; and respect for personal autonomy. Throughout, we connect stages of the argument pattern to examples of AI/AS applications. This helps to show its initial plausibility.

The aim of this paper is to shape the debate around adapting the assurance case methodology to reason about ethically justifiable risk acceptance in the context of AI/AS. As a work in progress, we welcome comments to the corresponding author.

1. INTRODUCTION

Interdisciplinary discussions about Artificial Intelligence (AI) often start with a question about what the term ‘Artificial Intelligence’ actually means. What are we talking about when we

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1 Assuring Autonomy International Programme, Department of Computer Science, University of York. Corresponding author: zoe.porter@york.ac.uk
2 With thanks to the following for their helpful comments on an earlier draft of this paper: Dr Christopher Burr; Professor Richard Clegg; Dr Kate Devitt; Dr Richard Hawkins; Dr Christopher Jay; Dr Tom Lawton; Ivan Kyambadde; Dr Colin Paterson.
speak of systems that embody AI? How does AI relate to Machine Learning (ML)? What exactly is an autonomous system?

Though many different interpretations may be given, we take the general approach that AI is what enables a machine to do what it takes intelligence for a human to do. For the purposes of this paper, we work on the basis that this means, in engineering terms, a range of techniques listed in the definition given in the European Commission’s proposal for an Artificial Intelligence Act: Machine Learning (ML), including supervised, unsupervised, and reinforcement learning; Logic and knowledge-based approaches, including knowledge representation, inductive logic programming, symbolic reasoning, and expert systems; and Statistical approaches, Bayesian estimations, and search and optimization methods (European Commission 2021, Annexes). Although defining AI in terms of all of these techniques carries the risk of becoming outmoded - indeed, many systems which are now considered ‘traditional’ are encompassed by this definition of ‘AI’ - we adopt this definition because we want to take a broad view of AI, rather than identify it with any single technique, however dominant in current applications.

AI-enabled decision support systems (e.g. for use in medical diagnostics) we count as AI systems; they are therefore what we mean by the ‘AI’ bit of the ‘AI/AS’ descriptor used throughout this paper. By ‘autonomous system’ (AS), we mean a software-intensive system which can make decisions and take actions independently of direct, real-time human control, in complex, unpredictable environments, where adaptive performance may be required (Luckuck et al., 2019). Typically, autonomous systems embody ML. AS may be physical platforms situated in a real-world environment (e.g. unmanned autonomous ships), or purely digital systems (e.g. high-speed trading applications). Both AI systems and AS may also contain non-AI software components.

Over the past five to ten years, the ethical implications of AI-enabled and autonomous systems have been intensively debated. This has led “seemingly every organisation with a connection to technology policy ... [to] author or endorse a set of ethical principles for AI/AS” (Fjeld et al., 2020, p. 4). These declarations and sets of ethical principles are now starting to translate into hard and soft regulation, such as the European Commission's draft proposal for an Artificial Intelligence Act, published in April 2021, the IEEE’s P7000 series of ‘ethical standards,’ and the UK’s upcoming White Paper on Regulating AI (European Commission, 2021, Annexes).

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To clarify, this is an ‘autonomous system’ in the sense of machine autonomy, and is not intended to describe human and biological autonomous systems, or autonomous nations, or autonomous systems of other kinds.
There is also a great deal of research focused on producing specific tools, methods, and processes to achieve ethical AI/AS, including audit trails, datasheets, model cards, AI ‘explainability’ techniques, red-teaming, ethical black boxes, impact assessments, certification, and conformity assessment (CDEI, 2021; Koshiyama et al., 2021; Falco et al., 2021).

In this paper, we contribute to a growing position within the AI/AS ethics community: the position that assurance cases, a specific kind of methodology typically used to achieve confidence in the technical safety of high-risk systems, look promising as a way to translate ethical principles into auditable, operationally-specific practice in the development and deployment of AI/AS. We present a prototype argument template showing how the assurance case methodology might effectively be used for this purpose. This template is called the principles-based ethical assurance (PBEA) argument pattern.

The intention is that the PBEA argument pattern could be used by developers, producers, operators or regulators to construct and present a case that one would be warranted in having confidence that use of a given AI/AS would be ethically acceptable in its intended context.

We define ‘ethically acceptable AI/AS’ as follows:

The engineering of the AI/AS, its outputs, its use, and its outcomes align with, and remain aligned with, people’s reasonable expectations of fairness, and respect for their welfare and autonomy as individuals, as well as for the welfare of society and the environments in which they live.4

This is a broad definition. It includes three subjects (individual, society, and environment). It requires that an ethical perspective is taken across the system’s lifecycle, from the engineering of the AI/AS (including design, development, and testing), through to use and maintenance, through to the consequences of its use in living environments. We assume that, even if the users have good intentions, the use of a system cannot be satisfactorily ethical if earlier stages of the lifecycle are not conducted ethically, and that it is also possible for a system to be engineered ethically and misused. In the presentation of the PBEA argument pattern, therefore, we focus on use, motivated by the recognition that this is of the highest generality and perhaps the greatest value. The coverage is also broad, encompassing core ethical values.

4 The phrase ‘people’s expectations’ could be interpreted in either a descriptive sense (what people do expect) or a normative sense (what people should expect). The definition is intended to express the normative sense.
of fairness, welfare, and personal autonomy. To note, the goal is ethical acceptability not ethical perfection. Even if logically possible, ethical perfection is not a realistic goal for practitioners. But we suggest that the bar for ethical acceptability should be high.

The rest of the paper is structured as follows.

**Section 2** introduces the assurance case methodology. It outlines one widely used graphical notation of that methodology - the Goal Structuring Notation (GSN) - for the documentation of argument patterns and assurance cases. This section provides the methodological foundations of the PBEA argument pattern. We also situate the approach taken in this paper within the emerging research field of argument-based ethical assurance.

**Section 3** describes the four ethical principles that form the central structure of the PBEA argument pattern. These are: justice; beneficence; non-maleficence; and respect for personal autonomy. These are the conceptual and normative foundations of the PBEA. We explain the rationale for using these four principles, which have their origin in medical ethics, in the context of the ethical assurance of AI/AS.

Building on these foundations, we construct the PBEA argument pattern. **Section 4** provides an overview of the argument pattern and its logical flow, in GSN. **Section 5** describes its decomposition in more detail, illustrated with examples.

**Section 6** highlights avenues for future exploration and research, including the role the PBEA argument pattern could play in the current and foreseeable regulatory ecosystem around AI/AS.

## 2. ASSURANCE CASES AND THE GOAL STRUCTURING NOTATION

### 2.1. The Assurance Case Methodology

‘Assurance’ refers to the general activity of providing justified confidence in a property of interest. Within engineering, that property of interest is, most commonly, safety. The assurance case methodology, specifically for safety, is used to “present a clear, comprehensive and defensible argument that a system is acceptably safe to operate within a particular context” (Kelly, 1998, p. 3). Assurance cases are often required as part of the regulatory process. In highly-regulated sectors, such as defence, aviation and healthcare, they tend to
inform pre-deployment certification of a system as safe to operate. Different drivers have led to the adoption of assurance and safety cases in industry (Sujan et. al., 2016). High profile accidents are one key driver. For example, following the Piper Alpha oil platform explosion in 1988, the public inquiry chaired by Lord Cullen led to the formal adoption of safety cases in the UK offshore industry (Lord Cullen, 1991). Another key driver is system complexity and its potential impact on safety management. This is best illustrated by the requirement for safety cases by the automotive standard ISO 26262 (ISO, 2011), prompted by the increased technical complexity of the embedded electronics as well as the organisational complexity of the supply chain.

Assurance cases are ‘living,’ not static, documents: they are designed to be updated, given changes in the system and its environment, in order to maintain confidence in the actual behaviour and use of the system (Denney, Pai & Habli, 2015). In what follows, when we speak of an ‘assurance argument pattern,’ we mean general, reusable templates for reasoning about a particular issue at an abstract level (Kelly and McDermid, 1997). When we speak of an ‘assurance case,’ we mean instantiated, systematic, auditable, and compelling argument that a given system (or service or organisation) will operate as intended for a defined application in a defined environment. Assurance cases are supported by a body of evidence, and assumptions are made explicit (SCSC-141C; ISO/IEC/IEEE 15026-1:2019).

Assurance cases are widely used in safety-critical systems engineering for several reasons (Habli, Alexander & Hawkins, 2021; The Health Foundation, 2012). First, the methodology is one of abductive reasoning: building confidence in an argument’s conclusion - the top-level claim - by way of inference from the best justification (Sakama, 2018). This approach is fitting for the conditions of complexity, dynamism, and uncertainty in which many high-risk systems are deployed. Second, the methodology encourages explicitness of argumentation, which provides a good basis for critical scrutiny and iterative revision to reflect new evidence and learning. Third, assurance cases promote structured reasoning amongst decision-makers. Fourth, they function as a ‘tool of tools,’ able to incorporate several other assurance mechanisms (e.g. audits) within their overall structure, as well as evidence from multiple sources. The consolidatory role of assurance cases has made them a primary requirement for demonstrating compliance with national and international standards (e.g. ISO, 2011). Finally, because of their explicitness, their clarity, and their dialogical form, assurance cases can foster interdisciplinary and multidisciplinary collaboration.5

5To clarify, we take ‘interdisciplinary’ to mean the synthesis of different disciplinary perspectives in the final research output, and ‘multidisciplinary’ to mean the drawing upon different disciplines that still stay within their boundaries in the research output (Choi and Pak, 2006). As an example, this paper puts forward an interdisciplinary proposal.
Assurance cases can be presented using different notations. One standard notation is the Goal-Structuring Notation (GSN), which was developed at the University of York in the 1990s (Kelly, 1998; McDermid, 1994). It is based on a model of informal argumentation promoted by Stephen Toulmin (1958). GSN places an emphasis on well-structured justification. Assurance cases structured in accordance with GSN are hierarchically decomposing: they argue back from a top-level goal - the key claim that the argument supports - via an argument strategy which elucidates an inference between a goal and the sub-goals that support it. These sub-goals in turn are supported by evidence and data. The argument strategy, sub-goals, and their supporting evidence together provide abductive support for the claim expressed in the top-level goal. As Goodenough and colleagues put it, “an assurance case provides defeasible reasons for believing that a claim is true” (Goodenough et al., 2012, p. 27). The main symbols and elements of a GSN assurance argument are presented in Figure 1 below.

Figure 1: Symbols and elements of a GSN argument, extracted and adapted from Assurance Case Working Group (2021)

2.2. Beyond Safety Assurance: Assuring the Ethics of AI/AS

The idea of extending the assurance case methodology to achieve the ethical assurance of AI/AS is an emerging one within the trustworthy AI/AS literature. The proposal to develop assurance cases as a structured method to assure a broad range of ethical properties has received its most sustained support in a recent paper by Burr and Leslie at the Alan Turing Institute (Burr and Leslie, 2022), following an early defence of this idea in an Annex to the ICO/Turing guidance on ‘Explaining Decisions Made with AI’ (ICO/Turing, 2020). It also received an early articulation in a paper by Menon and Alexander (Menon and Alexander, 2020) (see also: Hauer, Adler & Zweig, 2021).
The distinctive features of assurance cases outlined above are particularly salient in the context of ethical assurance. Abductive reasoning is appropriate for ethical decision-making, where conclusions are rarely certain, and there may be several plausible ways to justify key claims. Moreover, the explicitness of the methodology - which enables assurance cases to be scrutinised - is of central value if the use of the systems is going to be ethically acceptable over the long term. Scrutiny aids discussion, open debate, and continued improvement. That the method is a ‘tool of tools’ is a particular strength given the vast number of tools or mechanisms that are being proposed to deal with the ethical implications of AI/AS and the increasing need to organise all of the material in practicable ways (CDEI, 2021). Furthermore, interdisciplinarity and multidisciplinarity is key to effective solutions in the complex arena of ethical AI/AS, which involves not just design and engineering practice, but the involvement of human factors experts, as well as the perspectives of ethicists, regulators, social scientists, and lawyers.

There is already a healthy pluralism in the new field of argument-based ethical assurance. Some address discrete ethical properties, such as equity, in separate and distinct ethical assurance argument patterns (Hauer, Adler & Zweig, 2021). Others see merit in using the methodology to achieve justified confidence in a range of ethical desiderata within a single argument pattern (Menon and Alexander, 2020). With the PBEA argument pattern, we also take this wider approach. Our aim is to cover a complex set of interrelated but often disparate ethical considerations that need to be addressed to justify claims of overall ethical acceptability. There may be increased utility of the methodology if this is possible, particularly given that it also provides a framework for reasoning about trade-offs between different ethical values.

Another emerging variation in the new field of ethical assurance is whether the argument patterns should be created through a ‘bottom-up’ or a ‘top-down’ development process. In a ‘bottom-up’ process, directly affected stakeholders might create the argument pattern themselves in a participatory design process (Stilgoe, Owen & Macnaghten, 2013). The approach taken by Menon and Alexander (2020) and Hauer, Adler and Zweig (2021) is more ‘top-down’: researchers specify the structure and decomposition of the assurance argument.

The approach taken in this paper is a ‘hybrid’ one: a combination of ‘top-down’ and ‘bottom-up’. The ‘top-down’ element is that the central argument pattern is structured around four core ethical principles. This is specified by researchers - us - and it builds upon work done by other researchers in AI/AS ethics. This specification provides a detailed template. But the intent is
that both the instantiation and validation of individual ethical assurance cases which use the PBEA argument pattern as a template will reflect the ethical concerns of directly affected stakeholders. Furthermore, both during instantiation and validation this may lead to revising the PBEA argument pattern overall or adapting it to specific use cases. This is the ‘bottom-up’ element of the process.

Not all uses of the ethical assurance case methodology adopt GSN. But GSN is the notation used in this paper’s argument because of its widespread use in industry (University of York, 2014), the existence of a detailed standard (SCSC-141c), and the explicit support of argument patterns (Kelly and McDermid, 1997).

3. ETHICAL PRINCIPLES FOR AI AND AUTONOMOUS SYSTEMS

The PBEA argument pattern is structured around four core ethical principles. These have their origin in the four principles of biomedical ethics proposed by Beauchamp and Childress (1979, 2009). In 3.1, we describe those principles. In 3.2, we give the rationale for using them in this context. In 3.3, we address some of the criticisms of the ‘four principles’ approach in medical ethics.

3.1. Ethical Values and Principles for AI/AS

Ethical principles are ethical values expressed in normative form. In other words, ethical principles endorse or recommend behaviour which promotes certain ideals, such as equity, which are appropriately valued by people. Ethical principles are not absolute: they allow for discretion (O’Neill, 2001). In some situations, they may be rejected or infringed given the particular context or demands of a situation, or in the light of new evidence or disclosures.

Between 2014 and 2019, well over 80 major sets of ethical principles were published by intergovernmental organisations and national governments, public bodies, NGOs, corporations, and professional institutes (Fjeld et al., 2020; Jobin, Ienca & Vayena, 2019). Some scholars have identified a substantive overlap between the core themes that have emerged from these documents and the traditional principles of medical ethics (Morley et al., 2020; Floridi et al., 2018). The overlap has been endorsed by the OECD, amongst others (Mittlestadt, 2019). The identification of this overlap is an insight that we build on this paper.
The four traditional principles of medical ethics were first developed and articulated by Beauchamp and Childress in 1979 (Beauchamp and Childress, 1979, 2009).

The four principles are:

- The principle of non-maleficence, which imposes an obligation not to inflict (unjustified) harm;
- The principle of beneficence, which requires positively providing benefits to others and contributing to their welfare;
- The principle of respect for personal autonomy, which requires that people have the capacity to live according to their own reasons and motives, and to be free from the undue control of others;
- The principle of justice, which requires that benefits and burdens of any policy, procedure, or intervention are equitably distributed across the people concerned.

The approach to medical ethics that is grounded in these principles has come to be known as ‘principlism’ or the ‘four principles approach’. The four principles approach was motivated by the need to provide an ethical framework, reflecting a common morality, for guiding clinicians in medical dilemmas where different values are at stake without either over-simplifying the complexity of those dilemmas or getting immersed in intractable disagreements at the level of ethical theory (Holland, 2015).

3.2. Rationale for structuring the ethical assurance argument pattern around the four principles of medical ethics

This paper advances the position that the four principles also have a clear relevance to the ethics of AI/AS. Naturally, there are substantial contextual differences between medical ethics and ethical AI/AS. It is important to emphasise that, while we acknowledge the origins of the four principles in the field of medical ethics, the PBEA argument pattern adapts and adjusts these principles to this new domain of AI/AS ethics. To emphasise also, the position advanced here is that the relevance of these four principles, suitably adapted, is not limited to medical AI/AS.

In this subsection, we give the rationale for structuring the assurance argument pattern around the four principles of non-maleficence, beneficence, respect for personal autonomy, and justice. We see four reasons to justify the approach. First, it builds on a starting point already identified from meta-reviews of the sets of ethics declarations for AI/AS. Second, these
principles do seem to express core ethical values that are at stake with the use of any given AI/AS. Third, our particular approach to two of the ethical principles - beneficence and non-maleficence - is flexible enough enough to include a broad range of the actual concerns of affected stakeholders. Fourth, there are pragmatic reasons to structure the argument around these core principles. We take each of these in turn.

There is widespread agreement about the core values the ethical AI/AS field should focus on (Whittlestone et al. 2019). These are core values that have, broadly speaking, been rationally endorsed as salient by researchers and policymakers. They include, amongst others: benefit to the common good; harm avoidance; respect for people's rights; fairness; privacy; transparency, and autonomy (Whittlestone et al. 2019). That is not to say that communities of researchers and policymakers always get things right, nor that they do not have ‘blindspots’ about what matters to others, nor that the core values at stake may not change or evolve over time, but it does establish a starting point. The first part of our rationale for structuring the PBEA argument pattern around these four principles is that it builds on this consensu and, specifically, it draws on the insight that the range of core ethical values can be distilled into a framework of four core principles (Floridi and Cowls, 2021; Hagendorff, 2020; Morley et al., 2020; Floridi et al., 2018).

The claim that the range of ethical values can be distilled into a framework of the four principles is illustrated in Table 1 below.

| Principle Covers | Beneficence | Non-maleficence | Personal Autonomy | Justice |
|------------------|-------------|-----------------|-------------------|---------|
| Welfare          | Welfare     | Human control   | Fairness          |
| Flourishing      | Safety      | Dignity         | Equity            |
| Sustainability   | Security    | Privacy         | Privacy           |
| The common good  | Privacy     | Reciprocity     | Non-discrimination|
|                  | Non-discrimination |            | Reciprocity       |
|                  |              |                 | Responsibility    |
|                  |              |                 | (legal and moral) |

Table 1:
Coverage of the four core ethical principles

6 The seminal meta-reviews of the many sets of ethical principles proposed for AI/AS also offer an excellent insight into this consensus. See, in particular: Fjeld et al., 2020; Jobin, Ienca & Vayena, 2019.

7 Not all of the proposed ‘sub-principles’ or ‘values to be protected’ fit neatly under one principle alone. Invasions to privacy, for example, may be harms, threats to personal autonomy, and injustices (and against some laws, e.g. General Data Protection Regulation (GDPR) and UK Data Protection Act 2018). And some of the principles identified in the meta-reviews are not clearly derivative upon the proposed four. ‘Trustworthiness’ and ‘respect for human values’ are two that have been proposed where this seems to be the case (Fjeld et al., 2020). Even so, these are related to the four core principles. For example, enacting the four principles together would demonstrate ‘trustworthiness’ and ‘respect for human values’. Another principle that has been identified in the meta-reviews, and does not clearly fit into this schema, is the principle of solidarity (Jobin et al., 2019). It seems to us that solidarity - a sense
Transparency - which is often endorsed as an essential ethical desideratum in this context - stands orthogonal to this framework. It is best understood as an enabling condition (Turilli and Floridi, 2009). This is discussed further in section 5.5. The role of transparency in the PBEA argument pattern is to support the enactment of each of the four core ethical principles.

It is beyond the scope of this paper fully to justify the claim that all of the ethical values expressed in Table 1, along with transparency, represent the major ethical concerns for AI/AS. For present purposes, it is also beyond scope to explain comprehensively how the values can be taken to distil into the four core principles. But we do here offer independent support for the notion that the four principles express core ethical values of concern in AI/AS ethics, and in doing so we incorporate some of the values in each of the columns in Table 1. This forms the second part of the rationale for structuring the PBEA argument pattern around the four principles.

The principle of beneficence refers to an action intended to benefit other persons in morally relevant ways. We expand the scope of this to include benefits to society and to the environment. The term ‘beneficial’ is often included in descriptions of ethical AI/AS (Prunkl and Whittlestone, 2020). In our view, it is important to ensure that what makes an AI/AS beneficial is explicitly demonstrated. It is important to make clear what compelling moral reasons favour the deployment of the AI/AS in the first place. The moral reasons might be that use of the system promotes the welfare of individuals, societies, and/or the environment (or advances their flourishing, if people prefer a different school of thought). For example, use of the system might provide goods or advance capabilities that people, society, or the environment need, such as health or sustainability, or it might ameliorate an existing threat to those goods or capabilities. Either way, by explicitly including beneficence as a guiding ethical principle, we hope to reinforce that “there should be a (sought-after) benefit of having the system in the first place” (McDermid et. al., 2021, p. 4). This marks a significant shift in emphasis away from traditional safety assurance and risk acceptance practices.

The principle of non-maleficence “imposes an obligation not to inflict harm on others” (Beauchamp and Childress, 2009, p. 149). The real-world deployment of AI/AS to date has made it clear that the range of harm to people is extensive, and extends beyond bodily injury or fatalities to include psychological harms, whether trauma (e.g. PTSD), addictive behaviours, of unity, mutual attachment, and commitment to the common good - is also connected to the four principles in ways that do not undermine the approach we take. Rawls, for example, claims that solidarity plays a role in underwriting principles of justice (Rawls, 1971, pp. 90-91).
stress or anxiety (BS 8611: 2016). We also include here data-driven harms such as invasions of personal privacy and the misuse or theft of personal data (Veliz, 2020) and the risk harm from biased or discriminatory AI/AS outputs. Other individual harms might be economic, such as loss of access to an economic good, or political, such as disenfranchisement.

Possible societal harms from the deployment of an AI/AS include social fragmentation and the polarisation of social relationships, for example from hyper-personalised and bias-confirming algorithms (Leslie, 2019). There are possible societal dangers from widespread surveillance or the use of these systems to control or police society (Ada Lovelace, 2021) - or from security lapses in public systems. Risk of societal harm also includes threats to essential infrastructure, to energy and transport networks, and to markets (Hassel and Cedergren, 2021). Moreover, the individual harms described above also contribute to societal harm, for example by entrenching patterns of discrimination across society as a whole.

Furthermore, widespread deployment of AI/AS may have significant negative consequences on the environment (McDermid, Porter & Yia, 2021). This may be due to the aggregated impact of physically embodied systems on the environments in which they are used. Or it may be due to their design and construction. There is a significant carbon footprint involved in training ML models, for example, and it is unclear how this will ultimately affect greenhouse gas emissions when balanced against the energy savings they may also bring further down the line of deployment (Kaack et al., 2021). Environmental harm can affect both individual and societal welfare.

Avoiding physical harm is the arena of safety assurance and safety engineering; we therefore include safety under the principle of non-maleficence. This makes something clear: safety is not conceptually distinct from ethics; rather, safety is itself an ethical concern. However, the deployment of these novel technologies also prompts new questions about the identity of

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8 Discrimination is typically considered to be an injustice rather than a harm (since its wrong-making feature is generally explained in terms of fairness rather than harm; and not all discrimination necessarily causes harm) - a point we are grateful to Dr Chris Jay for emphasising. But we include discrimination under the principle of non-maleficence for two reasons. First, while discrimination might not always cause harm, such that a simple assimilation of harm and discrimination would be unsound, it will plausibly always be a hazard or possible source of harm. The injustice is that some groups will be disproportionately exposed to this harm. Second, discrimination is a risk that, we believe, would be more practicably dealt with at the non-maleficence stage of the argument (see section 5.4). To add, however, discrimination is also covered in the part of the argument that corresponds to the justice principle (as a sub-goal of JG3; see section 5.2 below).

9 The notorious COMPAS system, which disproportionately classified black defendants in the U.S. criminal justice system as presenting a severe recidivism risk, is a particularly well-known and egregious example of the problem of bias (Angwin et al., 2016). But the problem of algorithmic bias is endemic (see Noble, 2018; Eubanks, 2018; Wachter-Boettcher, 2017; O'Neill, 2016).
safety engineering, and its disciplinary boundaries, given the expanded range of harm to which they may give rise. We agree with Leslie that the whole field of ethical AI/AS has emerged largely in response to this extended range of harms (Leslie, 2019, p. 4). This underscores the inclusion of non-maleficence as a core principle in the structure of the PBEA argument pattern.

The principle of personal autonomy requires that a central element of a person’s dignity - their freedom and capacity to direct their own lives and actions - is respected by others. Personal autonomy is a rich philosophical concept which is replete with many different emphases (Rubel, Castro & Pham, 2021). For the purposes of the PBEA argument pattern, we work on the understanding that the term ‘personal autonomy’ refers to a person’s capacity to determine, live, and act according to their own reasons, beliefs, and preferences. This is a central ethical concern given the increasing influence AI/AS may have over human life and decision-making, whether directly or through the wider socio-technical systems in which they are integrated. Moreover, as systems increasingly replace human operators and decision-makers, who have been relied upon to exercise ethical sensitivity and judgement in situ (Burton et al., 2020), a new range of concerns arise about ‘meaningful control’ and whether the systems reflect the intentions and preferences of users and others in their operating environment (Santoni de Sio and van den Hoven, 2018). Managing these concerns falls under the principle of respect for personal autonomy.

The principle of justice is also subject to a rich variety of variations and distinctions within moral and political philosophy. What we take the principle of justice to refer to in the PBEA argument pattern is the requirement that the distribution of benefits, risks, and respect for personal autonomy across affected stakeholders should uphold notions of fairness or equity.\footnote{Note that for the purposes of this paper’s argument we include questions of substantive fairness, specifically whether the AI/AS’s outputs are discriminatory, under the principle of non-maleficence (see footnote 8).} Given the many trade-offs that are likely to arise between these elements, achieving a distribution that is equitable is both morally important and practically demanding. Achieving it involves ensuring reciprocity: that, for example, those who bear the risks of the use of an AI/AS are also its beneficiaries to a proportionate degree. AI/AS are disruptive technologies. Their deployment will likely shape human behaviours and the environments in which they are deployed quite radically. They may well transform the basic structures of society as a whole (Gabriel, 2022). Ensuring that this transformation rests on fair or equitable foundations is centrally important. In our view, it is preeminently so. As such, the ethical principle of justice takes methodological priority in the assurance argument pattern.
The third part of our rationale for structuring the assurance argument pattern around the four core principles is that it allows for substantial flexibility, specifically with respect to beneficence and non-maleficence. This is important because it can ensure that what affected stakeholders actually value in specific contexts can be incorporated and addressed. The idea is that, when instantiating an ethical assurance case based on the PBEA argument pattern, stakeholders will be able to highlight the ethically relevant benefits that they would like to derive from the use of the system, and conversely the specific risks of harm that they would like to see mitigated - benefits and risks which may well not have been identified in the current consensus amongst researchers and policymakers. It is not just the overall coverage the four principles provides, but also the flexibility that our particular usage of it for contextually-specific understandings of benefit and harm affords, that grounds the rationale for using these four ethical principles.

Fourth and finally, there is a pragmatic dimension to the rationale. The usability and memorability of the four principles has been tried and tested in the medical field. The four principles are memorable and workable. They have the potential to be an accessible heuristic for a wide range of non-philosophical professionals, including designers, engineers, safety teams, manufacturers, operators, and users. The four principles approach has several critics amongst academic bioethicists, but in practice, clinicians find them helpful to reason about medical dilemmas (Gillon, 1994). This is something our clinical colleagues support through anecdotal evidence.

This concludes our rationale for structuring the assurance argument pattern around the four core ethical principles, adopted but also adapted from medical ethics. We proceed on this basis. At the same time we recognise that future ethical values and principles might be proposed for AI/AS, and there may be existing ones we have not considered, that might not map onto this framework.

3.3. **Objections to the four core principles**

The four principles approach is controversial amongst academic medical ethicists. It is therefore worthwhile to respond to some of the common objections raised by medical ethicists against the approach. One objection is that working using them reductively masks deep moral and theoretical disagreements, such as what ‘doing good’ or ‘justice’ actually mean (Holm, 1995; Clouser and Gert, 1990). This does not fully apply to our case. In particular, the part of the PBEA argument pattern that addresses respect for personal autonomy rests on an
understanding of ‘personal autonomy’ as the morally important capacity of people to determine and act from, and for, their own reasons. And the justice argument broadly reflects a ‘social contract’ understanding of justice, such that what is just is not only equitable but justifiable, and that the central test for this is whether it would be agreed upon in a hypothetical (or actual) social contract amongst the affected parties (Weale, 2020). But beyond this, the PBEA also provides a structure for people to consider what beneficence and non-maleficence mean for them in relation to specific use cases of AI/AS, without unnecessary theoretical baggage. This strikes us as a strength rather than a weakness of the approach.

Others argue that principles are too rigid and prescriptive and override people’s “proper feeling for the deeper demands of ethics” (Toulmin, 1981, p. 37). This type of objection comes from a causist perspective: the school of thought that hard ethical cases should be considered as unique, and evaluated by analogy with paradigm cases that are similar in relevant respects (Jonsen and Toulmin, 1998). But there is no intention with the PBEA argument pattern that principles should be treated as algorithms that specify the optimal action in every situation. There is scope for judgement, interpretation, the weighing of reasons, and revision. This is enabled by the presentation of an argument pattern, which requires context-specific instantiation, rather than a rigid argument. Structuring the argument pattern or its instantiation around four core principles does not foreclose the possibility of considering the nuances of specific cases. Case-based reasoning can be complementary to a four principles framework (Beauchamp, 1995).

Some object that the four principles approach allows practitioners to ignore the kinds of uncertainties that characterise the most serious ethical problems (Callahan, 2003). There is no obvious reason, however, why a framework of four principles cannot accommodate epistemic uncertainty (uncertainty caused by a lack of knowledge) and moral uncertainty (uncertainty about the morally right thing to do). Indeed, there is scope in the PBEA argument pattern for uncertainty to be explicitly modelled and incorporated within decision-making (see section 5.2). Some critics argue that unresolvable conflicts will arise between the four principles (Clouser and Gert, 1990). Trade-offs are explicitly accommodated within the PBEA argument pattern. These are among the things that are reasoned about in the part of the argument pattern that corresponds to the principle of justice (see section 5.2).

It would seem that many of the objections that have been put forward against the four traditional principles of medical ethics lose something of their footing in the context of the specific assurance argument that we propose. But there is one central point of objection where we simply ‘bite the bullet.’ This is the objection that the set of four principles does not in fact
capture a universal, common morality (Trotter, 2020). We work on the assumption that they capture a ‘universal enough’ morality to ground efforts to achieve ethically acceptable AI/AS, but remain open to revising this assumption throughout our ongoing research.

4. Overview of the Principle-based Ethical Assurance Argument Pattern

Let us now present the PBEA at its highest level of generality, in its modular form. Modularity was introduced into GSN by Kelly, in 2001, in order to support a compositional approach to reasoning about complex systems, initially Integrated Modular Avionics (Bate and Kelly, 2003; Kelly, 2001). The modular form of the PBEA argument pattern is given in Figure 2 below.

Another key reason for modularity is to improve maintainability by creating loose coupling between the argument modules, which helps to control ripple effects (due to changes in certain modules on others).

Figure 2:
Modular structure of the PBEA argument pattern

The PBEA module at the top of Figure 2 contains the overall argument pattern’s highest-level goal. This goal is justified confidence in the truth of the claim that, for the intended purpose, the use of the system will be ethically acceptable in the intended context (see section 5.1).
Confidence in the argument pattern’s highest-level goal is immediately warranted by, or supported by, the justice assurance argument (JAA) module, which contains its own top-level goal: justified confidence in the truth of the claim that the distribution of benefit, risk, and respect for personal autonomy across all affected stakeholders is equitable and justifiable (see JG1, in Section 5.2 below).

The JAA module is, in turn, directly and conjointly supported by the beneficence assurance argument (BAA) module, the non-maleficence assurance argument (NAA) module, and the personal autonomy assurance argument (PAA) module. Each of these three argument modules (BAA, NAA, and PAA) serve a dual purpose. They address, insofar as this is possible, core ethical requirements on the use of an AI/AS (the realisation of benefits, the management of risks, and respect for the personal autonomy of those directly affected, respectively). And they also provide the data for deliberations about trade-offs between and distributions of these elements (benefits, risks, and respect for personal autonomy) within the JAA. This is explained further in subsections 5.2 - 5.5 below. In this way, the methodology yields a conceptual and normative framework for reasoning about ethically justifiable risk acceptance. The purpose of the transparency assurance argument module is to show that the relevant transparency requirements for each of the four principles have been met (see Section 5.6 for discussion).

Adjacent to the PBEA argument module is the Four Principles Confidence Argument module. This module is inspired by the idea, introduced by Hawkins and colleagues, of separating out the main safety argument in traditional safety assurance cases and the confidence argument (Hawkins et al. 2011). The confidence argument offers a more expressive and more sustained justification for a particular part of the argument than the use of the justification symbol and element in GSN (see Figure 1). We employ this approach too. The Four Principles Confidence Argument - justifying the use of the four core ethical principles of justice, beneficence, non-maleficence, and respect for personal autonomy - will distil the discussion in subsection 3.2 of this paper. In the next version of the paper, this Confidence Argument will be presented in an Annex.

5. The Principle-based Ethical Assurance Argument Pattern in detail

Now we can ‘open up the box’ of each PBEA argument module, presenting each decomposition in GSN.

5.1. The highest-level goal of the argument pattern
Figure 3 below details the highest-level goal of the PBEA argument pattern, and its immediately supporting argument elements.

As described in subsection 4, the highest-level goal of the PBEA argument pattern is justified or warranted confidence in the truth of the claim that, for the intended purpose, the use of the system will be ethically acceptable in the intended context (TG1).

This goal is situated within a series of explicit contextual definitions or statements, called ‘contextual artefacts’ (TC1-TC5). Let us now consider how those contextual artefacts would be instantiated. The definition of ‘ethically acceptable’ (TC1) has been given in the Introduction of this paper. We can flesh out the others through a hypothetical example of an autonomous ‘robo-taxi.’ The definition of the intended purpose might be that the robo-taxi should transport passengers without a safety driver within a specified operational design domain (ODD) (TC2). The definition of the usage might be that the robo-taxis take passengers from a city’s major railway station to various locations within the ODD, which is a 5-mile wide area in the city (TC3). The definition of the system would be its description, e.g., a cyber-physical system, with
a sense-understand-decide-act (or ‘SUDA’ loop) design pattern, the computational techniques used to build it, and so on (TC4). The intended context would be the environment in which it is used. This might include details such as: the position and relevant features of the particular railway station; the city’s weather conditions; relevant features of the population; typical traffic and pedestrian flow; and the precise limits of the ODD (TC5).

The argument strategy (TA1) is to warrant confidence in the argument’s highest-level goal (TG1) by demonstrating that each of the four ethical principles have been enacted in the structure that we set out, with the justice argument taking methodological priority. This strategy requires a further contextual artefact, namely a description of each of the four ethical principles of justice, beneficence, non-maleficence, and respect for personal autonomy (TC6). This description was given in section 2 of this paper. The argument strategy will be supported by the Four Principles Confidence Argument (PG1), presented here as an ‘away goal’ because it repeats a claim earlier represented in an argument module.

In sections 5.2 - 5.5 below, we consider each of the four principle-based assurance arguments and how they conjointly justify confidence in the PBEA argument pattern’s highest-level goal. Section 5.6 discusses the role of transparency in the argument.

5.2 The Justice Assurance Argument

As stated, our position is that, ultimately, it will be the equity and justification of the distribution of benefits, risks, and respect for personal autonomy (hereafter, b-r-p) that will support the highest-level claim to the overall ethical acceptability of the use of a given system. This falls under the aegis of the JAA.

Figure 4 below presents the decomposition of JAA, and elements within the JAA are explained beneath the diagram:
Figure 4: Decomposition of Justice Assurance Argument (JAA)
The top goal of the JAA (JG1) is that use of the AI/AS is both equitable and justifiable. By ‘equitable’ we mean, broadly, fair across all affected stakeholders (AC2), and by ‘justifiable’ we mean that use of the AI/AS is warranted on grounds that affected stakeholders could not reasonably reject, specifically because the decision to deploy or use the AI/AS would be agreed upon by these parties in a hypothetical (or actual) contract situation between them (AC3).

The central structure of the JAA is split into two argument strategies (JA1 and JA2). The argument strategy at (JA1) is to reason about b-r-p as three discrete or independent elements of ethical acceptability. This discrete reasoning is conducted in the BAA, NAA, and PAA, respectively (discussed in more detail in subsections 5.3, 5.4, and 5.5 below). It is important to note here a difference between our PBEA argument pattern and typical safety argument patterns. In the PBEA argument pattern that we present, sub-goals - in this case that the use of the system is beneficial (BG1), that the use of the system does not cause unjustified harm (NG1), and that use of the system does not unduly constrain people’s autonomy (AG1) - are achieved as far as is possible. But that is not the only function of the arguments represented in the away goals (BG1, NG1, and AG1) in Figure 4. As we started to describe in subsection 4, each of these three separate arguments (BAA, NAA and PAA) also yield informational elements - three matrices (AC5) - that feed up into the JAA.

This brings us to the second argument strategy at (JA2). The three matrices that are exported up to the JAA from the BAA, NAA, and PAA provide the basis for reasoning about b-r-p as connected elements of ethical acceptability. The benefits matrix describes benefits the system brings and for whom. The residual risk matrix describes what risks have been managed and what residual risks the system poses and for whom. The personal autonomy matrix describes what constraints on personal autonomy the system poses and for whom. As a speculative and very simplistic top-level example, these matrices evaluated together in the case of a manufacturing robot with autonomous capability might reveal that economic and productivity benefits to the manufacturer need to be weighed against residual safety risks and possible invasions to privacy to those in the ODD, as well as these individuals’ capacity to control the robot if it starts to malfunction. Justification for the highest-level goal of the overall argument (JG1) becomes complete once the reasoning about such distributions of b-r-p has been completed.

Let us now explain in more detail the decomposition of the argument from (JA2). In (JG2), the three matrices are integrated and certain distributions of b-r-p are eliminated. This
approach is inspired by the ethical risk analysis work of Hansson (2018), who describes ‘problematic role combinations.’ Because of constraints of space, we do not decompose (JG2) further in Figure 4. But we can elaborate here how problematic role combinations would be eliminated at (JG2). The roles are: decision-makers; beneficiaries; risk-bearers; and a subset of risk-bearers which we call autonomy risk-bearers.12

First, there should be no decision-maker who is a beneficiary but does not bear proportionate risk from deriving that benefit.13 Second, there should be no stakeholder who bears only risk from the AI/AS. For example, in the manufacturing robot case, it should not be the case that human factory workers in the ODD only bear risk, and no benefits to themselves, from the robot’s deployment. Third, no stakeholder who bears risk and only minimal benefit should be left uncompensated for that risk. This sub-goal is intended to deal primarily with concerns about unemployment as a result of AI/AS deployment. Fourth, no stakeholder should bear risk from the AI/AS whilst having their personal autonomy intolerably constrained. For example, human factory workers who bear the risks of harm from a malfunctioning robot should be able to intervene and stop it. And fifth, no beneficiary has their personal autonomy intolerably constrained. This is intended to capture the intuition that benefits may be imposed upon people who do not consent to them. Problematic role combinations would render the distribution of b-r-p ethically unacceptable. If problematic role combinations cannot be eliminated (or indirectly eliminated through mitigation in the case of the third suggested sub-goal), our working assumption is that it would not be ethically acceptable to deploy an AI/AS as described in (TC1) - (TC5).

Once problematic role combinations have been removed from the evaluation, in (JG3) we then select, from the three lined up matrices, the equitable remaining distributions of b-r-p. By ‘equitable distribution,’ we mean a distribution of b-r-p that is broadly ‘fair’ across all affected stakeholders (AC7). It should be noted that this admits of many possible answers in the field of moral and political philosophy, for example whether ‘equitable’ means giving priority to the worst off (Vallentyne, 2000). Given these debates, we do not yet decompose (JG3). However, one thing is clear: a distribution would not be equitable if it entrenched existing inequalities. This covers worries about digital inequity: the reinforcement of socio-economic inequalities

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12 Beneficiaries, risk-bearers, and autonomy risk-bearers are described in the contextual artefacts (BC2, NC2 and AC2) in the BAA, NAA, and PAA, respectively.
13 To note, decision-makers are not included amongst ‘all affected stakeholders’ but are captured in the decomposition of the JAA to guard against situations in which decision-makers disproportionately gain from exposing others to risk (Hansson, 2018). By ‘decision-maker,’ we mean those people who create, or set the conditions of, risk-exposure from the AI/AS (e.g. developers and regulators). It is expected that most decision-makers will also be beneficiaries and risk-bearers from use of the AI/AS, and it is in this capacity that they are otherwise represented in the argument.
due to lack of resources or access to technology. It may also cover concerns about unemployment. And it covers distributive injustices across protected demographic characteristics, the bases upon which people are protected by equalities legislation. In the UK, the characteristics protected by the Equality Act 2010 are: age; disability; gender reassignment; marriage and civil partnership; pregnancy and maternity; race; religion or belief; sex; and sexual orientation (Equality Act 2010). If it is not possible to select an equitable distribution of b\-r\-p, then our working assumption is that it would not be ethically acceptable to deploy an AI/AS as described in (TC1) - (TC5).

Following the selection of the equitable distributions of b\-r\-p, the final and crucial step in the justice assurance argument is to reason over them in (JG4). Our suggested approach here is to do so through a decision-procedure known as the ‘Wide Reflective Equilibrium’ (AC8). The ‘Reflective Equilibrium’ method is most closely associated with the work of the political philosopher John Rawls (Rawls, 1951; Rawls, 1971). It is a contractualist method because its aim is to yield an answer that is accepted by all those affected by the decision (in this case, the decision about which distributions of b\-r\-p from use of a given AI/AS are ethically acceptable).

On our understanding of the Wide Reflective Equilibrium as an actionable decision procedure to be employed in the JAA at (JG4), it involves affected stakeholders or their trusted representatives working back and forth between: a) ethical judgements or intuitions about the distributions of b\-r\-p in the case of the particular AI/AS in question, and trade-offs that may arise between them; b) general ethical principles (which may not be exclusive to the four core principles of beneficence, non-maleficence, respect for personal autonomy, and justice that are used to structure the argument); and c) relevant non-ethical beliefs and judgements (e.g. technical, legal) that should be factored into the decision. The inclusion of non-ethical judgements within the decision procedure renders it a ‘Wide’ Reflective Equilibrium (Daniels, 1979).

The aim is to reach a decision that represents an acceptable coherence among these judgements, principles, and non-ethical beliefs. Reflective equilibrium is reached when none of the parties involved in the process are any longer inclined to revise any of their judgements or beliefs, or the relative strength or weight of ethical principles, in order to endorse a particular distribution of b\-r\-p from use of the system. Our working hypothesis is that at least one distribution of b\-r\-p, and no more than a small number of such distributions, would be reached by the enactment of this procedure at (JG4). These distributions of b\-r\-p would therefore be both equitable and justifiable. In this way, JAA provides the justification for the top-level claim of the PBEA argument pattern.
5.3 The Beneficence Assurance Argument

The benefits that AI/AS will bring to humans and society is often the reason given for their development and deployment (DCMS, 2022, p. 4; HM Government, 2021). It is therefore striking that, within the sets of ethical principles for AI/AS, “references to non-maleficence outweigh those to beneficence by a factor of 1.5” (Jobin, Ienca and Vayena, 2019). The ethical principle of beneficence in this context endorses uses of AI/AS that are good for people, or that benefit them, for example by enabling them to have the goods or capabilities to fare well. The perspective taken in this paper is that it is not just the welfare of individuals that matters, but also of society and of the environment.

The degree to which an obligation of beneficence applies to for-profit corporations is an open question (Beauchamp, 2019). But it seems clear that regulators and public bodies do have such a special responsibility towards those affected by use of the system. If sector regulators were to use such a methodology to think about ethically acceptable risk, or if an ethical assurance case for AI/AS were to become something that regulators required, it is appropriate that the positive contribution it makes to human welfare is included as a consideration within the argument pattern. Moreover, developers and producers may well want to demonstrate what morally relevant benefits would be realised by use of the system.

The beneficence assurance argument (BAA) is in Figure 5 below, and explanations of its elements are given beneath the diagram:
The top-level claim of the BAA (BG1) is that the use of the system provides benefits to identified groups of beneficiaries. We can illustrate with the example of an existing medical AI system called ‘AI Clinician’ (Komorowski et al., 2018). The AI Clinician makes recommendations on one of two possible treatments of sepsis (vasopressors or intravenous fluids) for adult patients with a diagnosis of sepsis on Intensive Care Unit (ICU) wards. Here, the groups of possible beneficiaries, which would furnish the content of (BC2), include, at the individual level: i) the patient; ii) the individual clinician in-charge; iii) other clinicians and patients in the operating environment; and at the group level: iv) the hospital or NHS Trust; v) the developer or manufacturer of the system. With respect to the kinds of benefits the system could realise (BC3), to the patient, these could include improvements to physical well-being from targeted and effective interventions, and to the clinician in-charge the benefit could be the psychological benefit of well-supported decision-making as well as a reduced burden when many patients need to be attended to simultaneously. Indirectly, other patients on the ward and other clinicians may benefit, too. The benefits to the hospital could be greater efficiency, and indirect legal and financial benefits from increased patient safety and a better-supported clinical staff. The benefits to the developer or manufacturer would likely be financial and reputational.
The purpose of the BAA is to ensure that benefits are realised as far as is possible and also to capture this information in a ‘benefits matrix’ (BC4) as a precursor to deliberations about trade-offs between, and distributions of, b-r-p across all affected stakeholders within the JAA.

As a first pass, we think that the claim that the benefit has been realised should be supported by justified confidence in the truth of the following claims. First, that the kind of benefit has been described with the appropriate metric (BG3). This further decomposes into an appropriate description of the kind of benefit (BG6), its likelihood of being realised (BG7), and its impact (BG8). Second, there needs to be confidence that the methods used to realise the benefit in practice do in fact realise that benefit to a sufficient degree (BG4). Third, because assurance cases are not static documents, there needs to be confidence that the benefits from the system will be effectively monitored over its lifetime of use (BG5).

To return to the discussion in Section 2 of the ‘hybrid’ nature of the development of the PBEA argument pattern, we envisage that the directly affected stakeholders - those who use it, those who are in its ODD, and those who are on the receiving end of its outputs - are included in the discussions that lead to the instantiation of the benefits matrix. This is critical to ensure that the benefits that really matter to them are captured. Though the structure is constructed in a ‘top-down’ manner, the instatination of the argument in individual cases must include these voices in a ‘bottom-up’ process.

5.4 The Non-maleficence Assurance Argument

The ethical principle of non-maleficence imposes an obligation not to inflict unjustified harm on others (Beauchamp and Childress, 2009, p. 149). We include ‘unjustified’ because the idea is that some risk of harm may be warranted in the circumstances. Take, for example, medical procedures which involve some risk, or the simple act of driving one’s car to the shops. Activities and policies are rarely entirely risk-free in all respects, and it is not always unjustifiable to expose people to some risk of harm. Notwithstanding these questions, it is clear that harm should be avoided if the use of the AI/AS is to be ethically acceptable. This is what the non-maleficence assurance argument (NAA), presented in Figure 6 below, seeks to establish. We explain its elements in more detail after the presentation of the diagram:
Managing risks of harm is the traditional arena of safety assurance. To clarify upfront, the ethical assurance work we propose here is intended to run in complement to existing and established safety assurance activities and processes. However, a great deal of work in this arena can help in the articulation of the risks and their mitigations during instantiation of the PBEA argument pattern. Most commonly, safety assurance is driven by hazard-driven safety processes. A ‘hazard’ is a foreseeable potential harm, or a harm ‘waiting to happen’. In hazard-driven safety processes, engineers derive safety requirements as a means for constraining the design and use of the system so that the risk of hazardous behaviours is reduced to acceptable levels. Most influential safety standards are centred on, and commence with, hazard identification and risk assessment activities (ISO 2011; ISO 2019). As a result, the primary assurance argument in a safety case which has been produced in compliance with these standards tends to be risk-based and centred on the evidence recorded in a hazard log (or similar mechanism), which identifies how the risks associated with each hazard are controlled. The traditional focus of safety assurance is physical harm.

The NAA also extends wider than physical harm, and it extends beyond harm to the individual human. The top-level claim at (NG1) is that the use of the system does not cause unjustified
harm to identified risk-bearers. Returning to the earlier example of the robo-taxi, at the individual level, the likely risk-bearers identified in the contextual artefact (NC2) will be: i) end users of the service; ii) other individuals in the ODD; and also iii) human taxi drivers who once picked up fares at the taxi rank at the station and have been replaced. At the group or societal level, they include: iv) the service providers or operators; v) the municipal or city council; vi) developers and manufacturers; and also, indirectly, vii) regulatory bodies and certification agents, which would suffer reputational damage from the deployment of approved but ethically unacceptable systems.

The range of unjustified harm that might be incurred from the use of the given system is contained within the contextual artefact (NC3). In the robo-taxi example, in addition to the clear hazard of physical harm consequential upon unsafe design or use, there are the possible psychological harms of anxiety or stress to the user if the vehicle behaves erratically or dangerously. The economic exclusion of the replaced human taxi drivers would also need to be captured in the NAA; this would also be expected to incur psychological harm to those individuals. Moreover, aggregated over all replaced taxi drivers, use of this AI/AS could become a source of societal harm and economic exclusion. Another source of harm is discriminatory bias. In this context, the bias may arise because the systems have not been adequately trained on representative samples of the population demographic within the ODD. To take just one example, research has shown that the ML-models in self-driving cars have yet to deal with wheelchairs falling over backwards (Clegg, 2020). A further environmental hazard is that training ML models has a significant carbon footprint; it is unclear how this will ultimately affect greenhouse gas emissions when balanced against the energy savings such systems may also bring further down the line of deployment (Kaack et al., 2021). The hazards for the group actors listed above will be largely legal, financial, and reputational.

The purpose of the NAA is to ensure that risks are managed as far as is possible and also to capture this information in a ‘residual risk matrix’ (NC4) as a precursor to deliberations about trade-offs between, and distributions of, b-r-p across all affected stakeholders within the JAA.

We think that the claim that the risk has been managed should be supported by justified confidence in the truth of the following claims. First, that the kind of hazard from use of the AI/AS has been described with the appropriate metric (NG3). This further decomposes into an appropriate description of the kind of hazard that obtains (NG6), along with the traditional risk analysis approach of identifying the likelihood and severity of each hazard (NG7 and NG8, respectively). Second, there needs to be confidence that the mitigations in place are sufficient
(NG4). Third, there needs to be confidence that these hazards will be effectively monitored over the duration of system’s use (NG5).

As discussed in the context of BAA, and to return to the discussion in Section 2 of the ‘hybrid’ nature of the development of the PBEA argument pattern, we envisage that the directly affected stakeholders - those who use it, those who are in its ODD, and those who are on the receiving end of its outputs - are included in the discussions that lead to the instantiation of the residual risk matrix. This is critical to ensure that the risks that really matter to them are captured. Though the structure is constructed in a ‘top-down’ manner, the instatination of the argument in individual cases must include these voices in a ‘bottom-up’ process.

5.5 The Personal Autonomy Assurance Argument

In our view, determining the ethical acceptability of a system cannot simply consider risk and benefit, but should also consider what respect is given to the personal autonomy of those affected by the use of the system. The personal autonomy assurance argument (PAA) is presented in Figure 7 below, and explained in more detail after the diagram:
Figure 7: Personal Autonomy Assurance Argument (PAA)
The top-level claim of the PAA (AG1) is that the use of the system does not unduly constrain the personal autonomy of identified groups of ‘autonomy risk-bearers’ (AC2). These are the individuals whose capacity to live and act according to their own reasons, to exercise control over their own lives, may be directly impacted by use of the AI/AS. In the example of the manufacturing robot, these would be the factory workers where the robot is deployed, and possibly other workers in the corporation. In the robo-taxi example, these would be the individual users and other individuals in the ODD, such as pedestrians. In the case of the AI Clinician, they would be the patients and the overseeing clinicians, and, possibly, other individuals on the ward (imagine another clinician, for example, who cannot avoid the intrusive presence of the system when treating other patients).

The contextual artefact (AC3) makes explicit what kinds of scenarios would constitute a ‘constraint on personal autonomy.’ For the purposes of this argument pattern, we initially identify five such kinds of constraint in the PAA. These correspond to (AG5 - AG9).

The argument is structured by way of a strategy at (AA2) which organises the constraints to be addressed into two categories: constraints that correspond to the autonomy risk-bearers’ rational control over the AI/AS or its use and those that correspond to their physical control over the AI/AS or its use. By rational control, we mean that the individual in question can either act from their own reasons, or be involved in joint actions with AI/AS that reflect their intentions or are commensurate with how they reason about the world. By physical control, we mean manual, operational control. This distinction may contain assumptions that might strike philosophers as over-simplistic (given, for example, that physical control involves rational control and, typically, vice versa), but we hope that these infelicities may be forgiven as an attempt to organise the ethical concerns. Sub-goals (AG5 - AG8) address rational control. Sub-goal (AG9) addresses physical control. Collectively, (AG5 - AG9) furnish the kinds of constraint that are explicitly described in the contextual artefact (AC3).

(AG5) identifies the need to ensure that the use of the AI/AS does not unduly influence these stakeholders’ capacities to form their own preferences. This speaks to concerns about AI/AS which unduly manipulate people (Burr, Christiani & Ladyman, 2018; Yeung, 2017). (AG6) identifies the need to ensure that use of the AI/AS does not undermine their capacity to form their own beliefs. In the AI Clinician example, for example, there may be a risk that use of the system distorts the human clinicians’ own capacities to form true beliefs about the patient’s state.
(AG7) addresses the concern that the AI/AS should respond to those features of the world, and specifically the morally relevant features, that the autonomy risk-bearers would have them respond to. To take an example from the criminal justice domain, this might mean that the AI system should respond accurately to features that genuinely indicate criminal risk, and which are not proxies for discriminatory calculations of criminal risk based indirectly, for example, on race or socio-economic status. In the case of AI Clinician, it might mean that the system should reflect the overseeing clinician’s clinical intentions (Habli, Lawton & Porter, 2020). Though we do not decompose this sub-goal (AG7) further in Figure 7, we envisage it will incorporate the requirement that the features of the intended context that matter to these risk-bearers are reflected in design and deployment decisions about the system. Participatory design principles are therefore also integral to this element of the ethical assurance methodology proposed in this paper. Naturally, there may be conflict between those features that different groups of autonomy risk-bearers take to be morally relevant. While this is a question for further work, a guiding assumption is that these should be well-reasoned as far as possible - to use an extreme example to illustrate the point, racist opinions about what is morally salient could be discounted as being poorly-reasoned. But the JAA enables deeper resolution and consideration of such anomalies. Possible trade-offs between the perspectives of different groups of autonomy risk-bearers could be captured in the personal autonomy matrix (AC4) and considered in the JAA.

(AG8) addresses questions of informed consent, the notion that people should have sufficient information and the capacity to choose whether they are on the receiving end of an AI/AS’ operation. Where it is not feasible for each individual autonomy risk-bearer to give this, it seems acceptable that it is given by trusted regulators on their behalf. Again, we do not decompose this sub-goal further in Figure 9, but we anticipate that it would be supported by the appropriate organisational mechanisms in place to enable informed consent (whether direct or proxy) and that the relevant parties have the information they need for this consent truly to be ‘informed.’

Sub-goal (AG9) can be regarded as making reference to the autonomy risk-bearers’ physical control. Discussion of ‘meaningful human control’ over AI/AS tend to focus on the sorts of concerns addressed by (AG7) but also the capacity, which should be one that can be exercised effectively in practice, to stop or intervene in a system that is going awry (Santoni de Sio and van den Hoven, 2018). To take the example of the manufacturing robot, it should be possible, for example, for relevant individuals in the ODD to be able to switch it off if it starts to malfunction. Sub-goals which support (AG9) and are not given in Figure 7 include the requirements that autonomy risk-bearers’ have sufficient time, knowledge, and skills to
intervene effectively, and the controls are sufficiently accessible. Where this is not possible, there should be automatic controls in place for the system to stop safely, which includes a specific automatic function or the capacity of the system to enter a minimum risk condition (a low risk operating mode that the system - typically a physically embodied AS such as an autonomous vehicle - can execute when handover to the human operator fails or is not possible).

The purpose of the PAA is to capture the constraints on personal autonomy that have been addressed, and for whom (and how), and to manage them as far as is possible, and also to export this information up to the JAA in a ‘personal autonomy matrix’ (AC4), and as a component of deliberations about ethical acceptability within the JAA.

5.6. The Transparency Assurance Argument

We use the term ‘transparency’ to refer to the overall state of visibility around and about the system. This includes visibility both of human decision-making around the AI/AS across the lifecycle and visibility of what is going on ‘under the hood’ of the AI/AS. This aligns with the definition used within the recently published IEEE P7001 standard on transparency: “the transfer of information from an autonomous system or its designers to a stakeholder, which is honest, contains information relevant to the causes of some action, decision or behaviour and is presented at a level of abstraction and in a form meaningful to the stakeholder” (IEEE P7001-2021, p.14).

Within the PBEA argument pattern, transparency is not included as a core ethical principle in its own right. We view transparency ultimately as a means to an end rather than an end in itself. Whereas justice, beneficence, non-maleficence, and respect for personal autonomy are intrinsically important, transparency is instrumentally important. It is a ‘pro-ethical condition’ (Turilli and Floridi, 2009) or a condition that, when appropriately expressed, enables the enactment of the other four principles within the overall argument pattern. It is important to emphasise the need for caution here: some forms and approaches to transparency can be counter-productive to ethical acceptability. For example, excess transparency may in fact occlude or distract attention away from a developer’s intent, and it may also be used to undermine a user’s personal autonomy (Ananny and Crawford, 2018). Moreover, transparency is inimical to some security concerns. The equivocal role that transparency can play provides reason not to include it as a separate ethical principle within the PBEA argument pattern.
Different types and forms of transparency - including, but by no means limited to, the visibility afforded by AI explainability techniques - will be required by different stakeholders, at different points in the lifecycle, and for different reasons (McDermid et al., 2021; IEEE, P7001-2021; Ward and Habli, 2020; ICO/Turing, 2020). We do not, however, at this stage, open up the transparency argument module - this is a matter for future research.

6. DISCUSSION

This concludes our presentation of the PBEA argument pattern: a framework for reasoning about, and communicating, ethically acceptable risk from the use of specific AI/AS in well-defined intended contexts. One advantage of the framework is that it enables a range of disparate ethical concerns to be considered in a single, integrated argument. One of the central ethical questions about these new technologies is when the decision to deploy an AI/AS would be justified (Koopman et al., 2021). Given the novelty of the systems and the conditions of uncertainty in which, and for which, they are deployed, it is highly unlikely that regulators will get the answer to this question right with foresight alone. We believe the most practical and plausible way forward is to deploy ethically defensible systems and learn from experience during their operation. We propose that the PBEA argument pattern presented in this paper could provide precisely the sort of methodology required for informing and taking that step - and, because of the amenability of the method to reviewability, thus for incorporating learning from that initial deployment. In being explicit, dialogical, and reviewable, this methodology also carries the promise of being able to assure the ethical acceptability of the use of an AI/AS through-life.

The next stage for our research is to produce worked examples of the PBEA argument pattern with individual use cases, in order to develop specific ethical assurance cases based on this template. This will combine the ‘top-down’ approach of a pre-structured argument pattern with the ‘bottom-up’ elements of participatory design during the instantiation and validation of it. As we do so, we will consider if, how, and where aspects of the argument pattern may need to be revised.

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14 This was a theme that emerged during a workshop run by the Johns Hopkins’ Institute for Assured Autonomy in February 2022, attended by two of the authors.

15 Through-life assurance is a standard principle in safety-critical industries although the practice can be somewhat lacking. Its importance is increased for AI/AS given the high level of uncertainty about the actual performance of these systems in complex and often open operating environments. We see the issue of through-life monitoring and management of AI/AS being a critical research direction.
A second element of our ongoing research is the intersection of the PBEA argument pattern with the development of mechanisms to trace and allocate responsibility for the outputs and outcomes of AI/AS. The ultimate aim is to have a Responsibility Assurance Argument (RAA) that connects to various modules in the template we have proposed in this paper. The benefits and risks and constraints on personal autonomy identified in this paper, along with the justification of the decision to deploy, should all provide answers to the question of what decision-makers and other stakeholders might be responsible for. But there remains complex and open questions both about these parties’ forwards-looking responsibilities (their legal and moral obligations) and about their backwards-looking responsibilities (their liability or blame) for adverse outcomes consequent upon the design, development, governance, and use of the AI/AS, which are the subject of continued research.

The regulatory ecosystem around AI/AS is maturing rapidly. A wide range of regulatory interventions, practical tools, and technical methods are being developed. Their purpose is to ensure that both the human activity around the systems (e.g. the meeting of various obligations) and various properties of the systems themselves (e.g. privacy protection and fairness) meet the high standards we might expect if AI/AS are to be considered trustworthy. Our hope is that the PBEA argument pattern will play a valuable role in this regulatory ecosystem for several reasons. First, it can serve a useful consolidatory function, providing a framework for reasoning about both the relevant human activity and the relevant technical properties necessary to achieve acceptably ethical uses of AI/AS, including trade-offs between core values or desiderata. The argument pattern is also consolidatory insofar as it can incorporate several practical tools (e.g. audits, impact assessments) and technical methods (e.g. fairness metrics) within its structure, typically as evidence that would support sub-goals or claims. As the regulatory terrain gets ever more complex, ‘tools of tools’ look set to be increasingly useful - and this is something the PBEA argument pattern could provide. Second, arguments based on the PBEA argument pattern can serve a justificatory function, providing not just statements that certain desiderata or goals have been achieved, but an indication of how meeting these goals warrants confidence in the top-level claim to ethical acceptability of the AI/AS and how the decision to deploy or use such a given AI/AS could be justified, on ethical grounds, to those affected by it.

The third dimension of ongoing research is mapping the framework against requirements in draft legislation, such as the European Commission’s proposed Artificial Intelligence Act, as well as the UK’s position on AI regulation (European Commission, 2021; DCMS, 2022). Floridi and Cowls offer several examples of regulations and guidelines that already exist and which can be subsumed under the aegis of the four principles (Floridi and Cowls 2021). To take one
example, the European Commission's proposal for the world's first legal framework for the governance of AI emphasises safety and the fundamental rights and freedoms of citizens. (European Commission 2021). These requirements can be understood as falling under the principles of non-maleficence (safety), justice and non-maleficence (rights), and respect for autonomy (freedoms), respectively. Though the PBEA framework might not intersect exactly with all proposed regulation, our hypothesis is that it will be consistent with proposed regulation in many respects, as well as having standalone utility as a practical methodology to achieve ethically acceptable AI and autonomous systems.

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