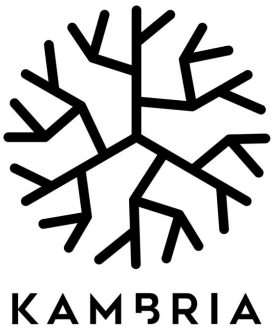

Fueling the Robotics Economy

Technical White Paper - Draft v0.3

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kambria.io info@kambria.io

Abstract

Kambria is an open innovation platform that will foster a collaborative ecosystem, with the goal of dramatically accelerating development and adoption of the world's most advanced robotics technology.

Current progress in the robotics industry is impeded by siloed development, wasted labor, and high startup cost. As a result, the pace of robotics innovation is needlessly constrained. Kambria's creation was born out of our desire to accelerate this process by engaging a vast community of developers and tinkerers, providing them with the necessary tools, and connecting them through market demand.

Drawing inspiration from other widely popular open source operating systems like Linux and Android, the core of the Kambria platform is an open robotics repository comprising of a high-level behavior library and modular hardware components. The repository is designed to maximize reusability and collaboration during robotics development.

Incentivized by game theory and crypto-economics, the Kambria community of investors, robotics companies, contributors, manufacturers, and users are empowered to collaborate and help the ecosystem grow exponentially. Our common goal is to design and deliver the most capable yet affordable consumer robots at 10x the speed, efficiency, and ease. This will unlock substantial value in markets that are primed for technological transformation. Imagine a world where your ill stricken daughter doesn't have to miss out on playing with her grandma 10,000 miles away; where she can be safe alone; a world where she is given the best automated care around the clock; and where she can be educated by the best teachers in the comfort of her home. This reality can be achieved in a near future with the Kambria robotics innovation platform built by the community.

Interactions on the platform are facilitated by the Kambria Token (KAT). Companies can use tokens to issue bounty challenges which are awarded to projects when fulfilled. Individual or teams are rewarded with tokens for designs or code they contribute. Manufacturers earn tokens through production of robots and robotic parts. Community members use tokens to promote specific projects and fundraise for legal protection of the shared technology. Tokens can also be used to fairly capture the value created by the Kambria platform and sustain the growing community.

Contents

1. Introduction

1.1. Shortfalls of Modern Robotics

Within just a few decades of Alan Turing proposing the question: “Can machines think?”[1] and Joseph Engelberger developing the first robot prototype[2], robotic machines were adopted on a massive scale in the industrial work space. Robotic arms can be found on every assembly line, manufacturing automobiles or preparing meals. The revolution of industrial robots was fueled by advancement in computing power and artificial intelligence. The former allowed robots to be programmed. The latter gave robots complex reasoning ability. Coupled with sensors, robots could interact with the real world to handle a wide range of tasks. Large economic value, captured by specialty machines working around the clock, hastened the use of robotics on all manufacturing lines.

Although robots have fully affirmed their place on the industrial floor, they have not yet been adapted to the home. After more than half a century of research, progress has been slow in making affordable robots that can address our everyday needs. Traditional development processes used by robotics companies result in high cost production, effectively isolating the everyday consumer market. Only robots programmed to do very simple household tasks, such as vacuuming or mowing, were able to capitalize on the small profit margin. Highly functional robots, including the Honda Asimo[3] that can walk up the stairs and the Toyota’s Human Support Robot[4] that can fetch, only exist in research facilities due to their expensive price tags. Neither will be commercially viable in the near future.

It is clear that problems robotics engineers struggled with years ago are still prevalent today.

#1. Lack of good interfaces and abstraction layers for software, electrical, and mechanical systems.

- Leads to bias towards monolithic and non-modular designs
- Results in major redesign effort for any modifications
- Causes a circular effect that makes the design hard to reuse by others and continues the cycle of waste

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[1] Turing, A. M. *Computing Machinery and Intelligence.* http://loebner.net/Prizef/TuringArticle.html. Accessed September 21, 2017.
[2] “A Tribute to Joseph Engelberger.” https://www.robotics.org/joseph-engelberger/about.cfm. Accessed September 21, 2017.
[3] “Asimo - The World’s Most Advanced Humanoid Robot.” http://asimo.honda.com/. Accessed September 21, 2017.
[4] “Toyota - Partner Robot Family.” http://www.toyota-global.com/innovation/partner_robot/family_2.html. Accessed September 21, 2017.

- Reduces efficiency since no common point available for developers to work off in parallel

#2. Lack of tools, semantics, and methods to share parts of designs in distributed fashion.

- Many engineering domains (mechanical, electrical, etc.) lack good tools for collaboration and sharing.
- Missing semantic linkages across systems, including firmware to electrical engineering, electrical engineering to mechanical, and others.
    - Currently, it's a tangled state of repos, directories, sheets of BOM parts, text assembly instructions, slicer settings, and supplier names in scattered local servers and cloud storages.

#3. Significant portions of expended effort are implicitly discarded.

- Similar to the practice of discarding a rocket after each use, before the breakthroughs by SpaceX which made multiple landings of its Falcon 9 rockets[5]
- Duplicated effort to find good suppliers, select parts, negotiate, verify paperwork, and assemble an in-house team
- Zero practical standards or instructions to capture the comprehensive start-to-end process information

#4. Cool robotic applications are slow, expensive and hard to make. Innovation is stifled.

- Inadequate infrastructure and high-level abstractions for robot programming
- Lack of open platform and dev tools to innovate upon
- Most explorative development is bootstrapped. A labor of love at present
- Capital funding is only offered to large scale or mature projects

#5. Slow turnaround, high minimums, and poor interfaces from "traditional" manufacturers.

- Has massive impact on development speed
- Are the bottlenecks in the design/build/test cycle
- Results in higher costs, time, and effort

Due to the above challenges, the current pace of robotics innovation is needlessly constrained. The ultimate purpose of this proposal is to free the robotics industry from these monolithic restraints and accelerate the evolution of robotics technologies. We believe that the future is too important to belong only in the control of a select few entities. It is ethically responsible that we ensure the development of robots will be more equitable and utilitarian if such robots are to replace millions of jobs currently held by humans. We must find ways to collectively own, govern, and benefit from the coming revolution in robotics.

[5] "SpaceX - Falcon 9." http://www.spacex.com/falcon9. Accessed September 21, 2017.

1.2. Ohmni Robot

Our founders started a robotics company in 2015. It was built upon the premise that to really accelerate adoption of robotics in the homes, a new type of company was needed. Being far away from home ourselves, we could relate to the needs for affordable robots that bring families closer. So we set out to design robots with modular components, and utilize lean, toolless manufacture. To close the cost gap, we were ultra-focused on iteration speed. Reusability and integration were the cornerstones of our fabrication process, allowing for orders of magnitude less capital spent and a fraction of the development time.

In the short span of just two years, we were able to prototype ten generations of a telepresence robot. The net result, Ohmni, quickly became one of the leading products in the consumer market at an unmatched price point. Ohmni's mobility, range, simple controls and easy access appealed to users of all ages and backgrounds. Using our robot, families that were separated by countries, continents, or oceans could feel the distance fade away. Children confined by their illnesses could still interact with their classmates and teachers. Ohmni was touted by NY Times as Rosie, the robot from "The Jetsons"[6] and CNN reported that "Ohmni robot makes video chats feel like they are in real life."[7]

Even though we had successfully brought a low-cost high-value robot to market by practicing our philosophy of ultra-lean, fast and agile manufacturing[8], our goal has always been to enhance the entire process, overcome existing shortfalls encountered in the industry, and jump start a revolution in robotics.

1.3. Mission Statement

Our mission is to accelerate the process of robotics innovation.

Being able to foster an open collaborative ecosystem, where every contribution can easily be shared, manufactured, and implemented, will be revolutionary. Companies can benefit from the collective contributions of the community to build custom applications without having to employ teams of PhDs. End users can enjoy the higher quality of life afforded by readily available robot

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[6] Gustke, C. The New York Times. *Seniors Welcome New, Battery-Powered Friends.* January 20, 2017. https://www.nytimes.com/2017/01/20/business/robots-ai-elder-care-assisted-living-retirement.html?_r=1.
[7] Yurieff, K. CNN. *Ohmni home robot makes video chats feel like they're IRL.* April 12, 2017. http://money.cnn.com/2017/04/12/technology/ohmnilabs-telepresence-robot-launch/.
[8] Leung, I. Forbes. *Meet the Hardware Startup that's Manufacturing Their Telepresence Robots in California.* August 21, 2017. https://www.forbes.com/sites/irisleung/2017/08/21/meet-the-hardware-startup-thats-manufacturing-their-telepresence-robots-in-california.

products and services. A combination of reduced costs, cutting edge technologies, and expedient delivery, will spur rapid adoption of the platform by companies, developers, and manufacturers. This cycle of innovation will pave the way for the *next* wave of robots to provide immense value for billions of people across the world.

In order to achieve this vision, we are contributing our robot Ohmni, consisting of a robotics repository, high level behavioral library, and modular components, as the basis for an open robotics innovation platform.

We named the platform **Kambria**, after the Cambrian Explosion, 500 million years ago, when an accelerated evolutionary rate gave rise to biodiversity and abundance. We believe this platform will be the catalyst for a similar explosion in Robotics.

1.4. Solution Enablers: Blockchain and Crypto-economics

"Bitcoin gives us, for the first time, a way for one Internet user to transfer a unique piece of digital property to another Internet user, such that the transfer is guaranteed to be safe and secure, everyone knows that the transfer has taken place, and nobody can challenge the legitimacy of the transfer. The consequences of this breakthrough are hard to overstate."

- Marc Andreessen, inventor of the first browser, thought leader and top VC.[9]

"Whilst open source has always had powerful network effects, the additional skin in the game through direct financial stake puts open-source token-backed initiatives on steroids."

- Jamie Burke, Outlier Ventures[10]

If one views the current state of robotics through the lens of game theory, one would recognize that participants are faced with two choices: cooperate (share technology and collaborate) or defect (remain secretive). As it stands, the industry as a whole remains cemented in the worst-outcome Nash equilibrium, where everyone defects. No one deviates from the strategy, because those who do, risk disadvantaging themselves. Competitors are likely to incorporate technology without giving anything back, and the company that spent the time and effort to share, receives nothing in return.

Transcending this paradigm means moving everyone to the pareto-optimal Nash equilibrium, one where collaborative innovation is a win-win. This requires adjusting the weights of the game, by significantly increasing the reward for cooperation while penalizing defection.

[9] "What is Blockchain Technology?" https://www.coindesk.com/information/what-is-blockchain-technology/ Accessed September 21, 2017

[10] "Community Token Economies White Paper." https://outlierventures.io/cte-wp Accessed September 21, 2017

Blockchain technology and crypto-economics provide a unique mechanism to deliver the desired rewards and enforce penalties to achieve this optimal equilibrium. As a decentralized distributed ledger, blockchain technology enables open collaboration without the opacity and inefficiency of traditional economic models.

Ethereum blockchain provides the decentralized structure on which Kambria is built. Ethereum allows for the development of a rich library of smart contracts to ensure execution of payment transfers and transparency for all interactions. Ethereum blockchain also allows for the existence of and democratic participation via Kambria token (cryptocurrency). Through the combination of smart contracts and tokens, an entire economy can be fostered to encourage or discourage work and transactions, in service of our common goal.

Kambria smart contracts and tokens are leveraged to reward cooperation and penalize defection in order to (1) dramatically lower barrier of entry for individuals and small teams to collaborate; (2) provide economic incentives to contribute; (3) capitalize on network effect and aggregate compelling technology; (4) provide intermediation for the end-to-end robotics business challenges; and (5) detect and denounce of fair use violations.

Ready-to-use Kambria technology and robot platforms provide an intermediation point. This allows passionate roboticists to continue improving and experimenting with new technology that *does not* necessitate immediate profitable use. Meanwhile, robot companies can dramatically shorten development cycles and focus on attaining product-market fit. As time progresses, the economic value of payoff for both token holders is significantly increased.

In the crypto space, it is also possible to raise sufficient capital to achieve what most venture capitals would not dare to do, that is: fund an incredibly valuable open source community. Moreover, the capital can be immediately deployed to aggregate enough compelling technology to develop state of the art Kambria-based robots at high value-to-cost ratio.

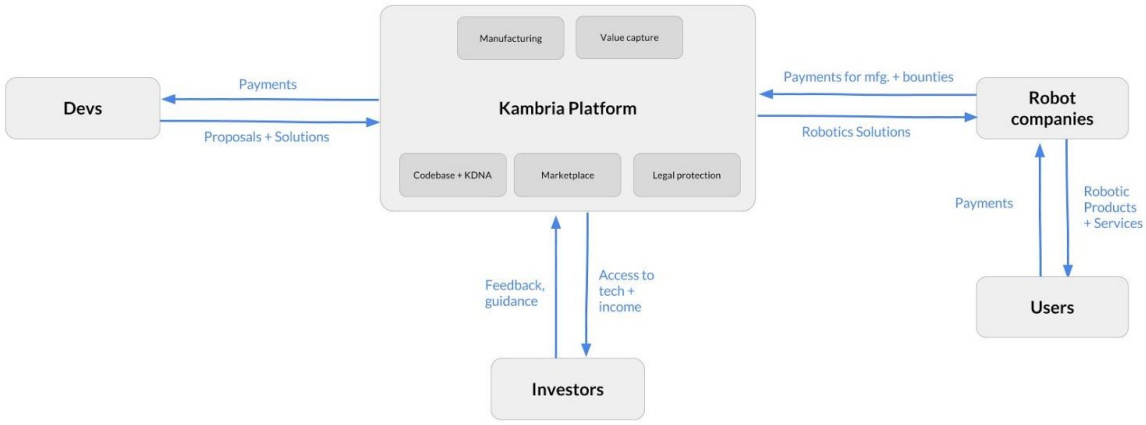
2. Kambria Architecture and Utility Token Model

The Kambria Architecture is made up of five pillars: K-DNA, marketplace, manufacturing alliance, value capture, and legal protection. Each directly addresses the shortfalls of modern robotics detailed in Section 1.1 and is designed to maximize the game theoretic incentives listed in Section 1.4.

Interactions on the platform are facilitated by the Kambria Token (KAT), Kambria Karma, and Kambria Credit. KAT is a native ERC20 utility token. Its main functions are to enable access to the Kambria platform, reward participation, and align incentives for all stakeholders in the ecosystem.

Kambria Karma and Credit are not ERC20 tokens, but rather non-tradeable ledger entries for every wallet address. Karma is used to track actual work performed. It is also an incentive to promote useful work and is awarded for concrete contributions. Credit is similar to reward point or "cash back". Its purpose is to stimulate transactions and spendings in the ecosystem. Details on each will be explained further in subsequent sections.

Below diagram offers a high level view of the stakeholders and the flows in the system. The detailed token flow diagram is available in the Appendix.



Why robotics developers use Kambria:

Without Kambria	**With Kambria**
High dev costs, high barriers to working on interesting stuff. And question of where to start, no good consensus-based starting points.	Reuse state-of-the-art, low-cost, fully-usable designs, algorithms, etc. from the Kambria codebase and focus your effort on just the part you are innovating on.
Requires hand-building of prototypes, hard to share with others, slow and not repeatable.	Use K-DNA + Kambria manufacturing to transform ideas/designs into concrete, functional parts an order of magnitude faster and cheaper.
Deal with manually pulling together people's work across many different Git repositories, Instructables guides, Google Docs. Figuring out how to get each piece made yourself.	Collaborate with people around the world on hardware projects more like software projects. One click and people around the world can obtain and be testing/iterating on the same new design.
Hard to find funding for robotics dev that may clearly be valuable but may not yet create a specific, capturable market opportunity. Means that roboticists must also spend time/energy on business and appealing to VCs if they want to go this route.	The bounty marketplace gives access to a massive amount of funding and a mechanism for the robotics community to determine what's valuable. At token sale time Kambria reserves ~30 million USD of tokens for bounties, grants, and partnerships to pull in top technology (details in section 3).
Given the high costs, to work on robotics, you typically need to find a robotics job. At most large companies all tech you develop is owned by them and either kept secret from the world or locked up in patents.	You and the entire Kambria community both share ownership of the work. It's visible to the world and publicly attributed to you. K-prizes give additional visibility for top work. The DARPA challenges have demonstrated the power of public robotics competitions to capture the public's interest and imagination.
Not as much incentive to share and maintain code as open source if a large company can	Value capture ensures that for the work developers contribute to the community, they

just take it, make money with it and you can't do anything about it.	can receive recurring payments for their work over time. Safety in numbers - Kambria's legal protection enables the entire community to detect, denounce, and follow up on unfair use by those outside the community.

Why robot companies use Kambria:

Without Kambria	**With Kambria**
Build up an entire robotics R&D team, and then on top of that supply chain management, manufacturing team and/or contract manufacturer partnerships, etc. Spend huge amounts of time and capital and divide your attention away from the market opportunity.	Massively reduce time and capital risks. Be prototyping your application in days or weeks instead of months or years. Build on top of ready-to-use but 100% customizable robots so you can focus on the 5% of innovation you need in your market and not redo the other 95%.
Struggle to find and hire robotics engineers with the right skills and experience. Often you need to assemble teams of PhDs and people across design, mechanical, electrical, and software domains. For physical work, you're often restricted to those near your physical HQ since they have to use your facility, tools, and supply chain.	Tap into a worldwide network of top roboticists and developers. K-DNA and Kambria manufacturing means if someone around the world proposes a great working solution, you can have the exact working part in hand just a few days later. Because they're also working off of and leveraging the entire Kambria codebase, AND likely are already experts in the area with cross-collaborators, development project costs can drop by 10-100x.
Evolve product slowly, redesigns and "V2" of your robot take months or years.	Ultra-rapid and continual iteration. Massively increased chance to find product-market fit.
Spend a large part of your engineering budget on cost optimizations, especially for robotics targeting consumer use.	For parts that aren't as critical, contribute them and let the community help reduce the costs. And because you contributed, gain Karma that translates to revenue if that part is

	reused by others, which offsets your costs. Every part in the robot can be seen as a potential revenue generating source rather than a cost.

Why investors participate in Kambria:

Without Kambria	**With Kambria**
Invest in a robotics company attacking a specific vertical market.	Reduce risk by investing in the broadly diversified technology that becomes the foundation for many different robotics companies across many verticals.
High R&D execution risks up to the point of validating product-market fit.	Reduce risk by enabling the company to prove product-market fit in a fraction of the time and more importantly with a fraction of the capital spent.
No liquidity until a future event - "all or nothing".	Immediate liquidity and flexibility.

Why users benefit from Kambria:

Without Kambria	**With Kambria**
Slow rate of overall robotic innovation. Long time before value-adding robotics can massively impact individual lives and society in a positive way.	Massively increase innovation rate. Widespread accessibility to fungible robotic labor on-demand in the future.
High cost of robotic products.	Large scale reuse and sharing of technology can reduce costs significantly to make useful robots affordable.
Monopolies on robotics by a small number of companies controlling all technology and all innovation.	Robotics technology as a social good, accessible to everyone. Many different niche robotics companies efficiently serving different user needs, but sharing 90%+ of the core technology. Open to new innovators.

2.1. K-DNA

Modularity is the essence of Kambria, and the basis for reusability and efficient collaboration.

Kambria DNA (K-DNA) is our semantically rich module management and build system. It crosses hardware, firmware, software, electrical, and mechanical boundaries to directly specify all components and subcomponents of a built robot. For example, the motor system that gives our telepresence robot mobility is a combination of electrical engineering (motor controller board), firmware (commutation algorithms), mechanical designs (housing, mounting, etc.), manufacturing processes, sourcing, assembly, tools, cabling, software (API), and much more.

The design of K-DNA is inspired by a combination of the *npm*[11] node.js package manager and the Android Open Source Project's *repo*[12] tool.

Each module is a Git repository which can be hosted on any cloud service (i.e. GitHub, Bitbucket), your own server, or perhaps stored in IPFS in the future for decentralization. Kambria's codebase architecture is designed to be pragmatic first by maximizing reuse of the tools that everyone is familiar with and already using.

Modules can be linked to Kambria's distributed module registry (the Kambria Codebase) which is a smart contract on the Ethereum blockchain. Registering the module only needs a publicly-accessible URI to the repo, and a unique name. As smart contracts have no access to the outside world, the Kambria foundation runs a verifier service/oracle which retrieves the owning wallet address from the repo directly (proof-of-ownership). This process does not certify any particular amount of work done or ownership, but links the repo into the registry. Furthermore, note that now every module/repository has the ability to hold, receive and send funds, and participate in on-chain mechanisms (voting, signaling, staking, etc.).

Each module also contains a root-level *kdna.yaml* file (YAML format) which is a semantic description of the contents of the module. This makes the system semantically processable - i.e. subdirectory A contains the firmware that's used on the PCB in subdirectory B, which is part of this particular CAD'ed mechanical assembly in subdirectory C. We use a simplified version of RDF triples to express these relationships in an extensible way.

The module kdna.yaml files also list dependencies on other modules by global name, with version constraints (like npm). The build system, like repo, can scan the on-chain registry and fetch all modules at appropriate versions from all repositories. The modules are projected into a directory hierarchy (like AOSP) and tools can be used to do things like compile across modules, generate bill of materials information, generate assembly instructions, export files for 3D

[11] https://www.npmjs.com/
[12] https://source.android.com/source/using-repo

printing, etc. In addition, Kambria developer tools will allow this semantically-rich data to be easily viewed and modified across all repositories.

There are additional rich game-theoretic and product interactions we want to explore here as well. Our goal is to discuss and experiment together with the robotics and crypto communities. For example, tipping projects/users with KAT, leaderboards and surfacing projects that hold the most KAT, reputation systems, other applications of Karma, periodic community-wide signaling rounds to estimate the value of each project, etc. By bringing projects and users on-chain, we'll have the flexibility to explore what approaches create the strongest incentive alignment.

The combination of open codebase, component language, and dev tools make up the core of the Kambria robotics innovation platform. K-DNA maximizes freedom, prevents lock-in, and empowers all current collaborative methods. **If you can dream it up and express it in K-DNA, you can get it made.**

2.2. Marketplace + Innovation Utility

The innovation marketplace is at the heart of Kambria's open innovation model. KAT tokens are used as both a top-down and bottom-up signaling mechanism, as well as a reward when value-adding work is completed.

Top-down signaling is driven by the desire for new technology to be added to Kambria, where the party or parties needing the technology want to find experts that can provide solutions. For example, a large company that wants to apply robotics to their own business may need a custom sensor, manipulator, or control logic. They can purchase an amount of KAT tokens and submit a bounty that describes: the work to be done, the judging criteria, expert judges from the community[13], tranches or timing, and a payout schedule. These are encoded in a smart contract on the Ethereum blockchain, with links to additional bounty data off-chain. The KAT tokens for the bounty are staked in the smart contract while the bounty remains open. (Withdrawals may be possible but likely subject to heavy restrictions, specifics to be determined later on.)

These bounties can range from small ($100-$5K USD) to large ($100K-500K USD) to enormous ($1M+ USD). Most importantly, others can join existing open bounties by staking their own KAT to increase the size of the prize pool, essentially directing the development of solutions based on the signaled needs of the community.

[13] Author's note: we favor contests with quantifiable and measurable results, so that judge selection is more efficient, i.e. can avoid having to do as detailed audits for impartiality. Thus, the judges can act more like executors, uploading proof-of-results off chain and referencing them on chain when awarding the bounties.

We include tranches/multiple tournament rounds in the bounty design as there may be financial overhead for innovative but poorly funded teams in some cases. If the bounty includes it, an early tranche based on a detailed project proposal may win a small set of funds to be used by the team for materials/spending required to reach the next tranche.

K-Prize is the name given to a set of widely publicized bounties/competitions with large prizes (typically $500k+ USD) that are run by the Kambria Foundation. These will target and push forward the development of key capabilities that unlock new value/application for robot platforms. These are modeled after the XPRIZE Challenges and other robotics competitions like the DARPA Challenges, RoboCup, as well as the various navigation or picking challenges held at various robotics conferences. These are key for demonstrating to the public the increasing usefulness and capabilities of the Kambria platform. The underlying bounty mechanism remains the same.

We also recognize that many corporations may need assistance purchasing KAT for bounties and thus the Kambria Foundation is dedicating a team and part of the holdings (in the form of the Community Fund) to guide/assist companies in making the process as easy as possible.

Continuing on, bottom-up signaling recognizes the importance and foresight of leading developers in the community in proposing new and important work. Every project or individual in the Kambria ecosystem can propose a GoFundMe or Kickstarter style project describing the work to be done and a desired contribution amount. Via a traditional curation/voting process the community can surface the top proposals, which are again stored on chain as smart contracts essentially using the same bounty mechanism with a few different bits.

As bounty work is completed and and validated, the smart contracts will disburse funds either immediately (based on multi-sig or other voting done by the appointed bounty judges) or set up a distribution schedule if the funds are to be released over time. We note that bounties distributed over time can provide financial stability to the winning teams and also incentivize them to keep engaging with the community. In either case, additional logic can be set up to be automatically triggered when the competition is concluded, such as ongoing maintenance contracts for the winning team to continue improving their code or designs.

The requirement to submitting a solution is that it must be done via the contest's smart contract by referencing the signed hash of the KDNA used to generate the solution. Thus, the winning solutions become open and immediately usable and replicable by the entire community. **Never before has cutting edge, prize-winning technology been immediately available and usable the next day by the entire robotics community.**

There are two other unique features that we've designed into the innovation token flow that provide game-theoretical incentives. First, we introduce the notion of maker credits. These are a simple mechanism to help to solve the first-mover problem. Essentially, as KATs are disbursed by the smart contract to various teams, all stakers receive maker credits in proportion

to their staked amount. For instance, if Alice staked 100 tokens, Bob staked 70, and Charlie staked 30, and 20 tokens were paid out, then Alice would receive 100/200 * 20 = 10 maker credits, Bob would receive 70/200 * 20 = 7 maker credits, and Charlie 30/200 * 20 = 3 maker credits. The maker credits are non-transferrable and have restricted use, i.e. they can only be spent inside the Kambria ecosystem, i.e. to pay for robots to be built, etc.

This mechanism acts similar to "cash back" for a credit card and helps soften the opportunity cost for participating in bounties. The community can vote on and adjust an appropriate reward rate, i.e. 1 maker credit is worth say 0.3 KAT when used for manufacturing. The simple theory behind this is that say a 1M USD bounty causes value to be created that ultimately will be more than 1M USD worth of long-term value to the community. Then the community should be willing to help soften the immediate opportunity cost as long as the entity receiving the credits spends them within the system.

Second and most importantly is our use of **Kambria Karma**. Karma is a non-transferrable ledger entry per account that entitles the holding account to share in a bonus of the fair use fees generated by the Kambria platform (mechanism described in section 2.4). The key is that Karma can not be generated from capital alone. It is only generated from key interactions in the system that require work. In this case, just as maker credits are generated when bounties are disbursed so is Karma. Initially, for each KAT disbursed, 0.5 Kambria Karma is issued to the awarded projects and 0.5 is awarded proportionally among the stakers. Changes to this ratio can be proposed and voted on in the future[14].

The combination of the short term maker credits and the long term bonuses from holding Kambria Karma give us the mechanism to solve the first-mover problem by providing a strong economic advantage to those who participate in issuing bounties. This enables the work to be shared openly across the entire community while rewarding those who participate early and often.

2.3. Next-generation Manufacturing Alliance and Manufacturing Utility

The Manufacturing Alliance will be a collaborative partnership where top manufacturers share knowledge, resources and maintain APIs/standards. The alliance’s common goal is to provide a network of ultra-lean and ultra-fast robotics manufacturing centers around the world.

Every member is committed to the open process of turning K-DNA into fabricated robots, quickly. This capability that eliminates the need for the supply chain, sourcing, negotiating,

[14] Author's note: currently, no percentage of the bounty disbursements is captured for the community itself. This aligns with the transfer of value within in the community. There may be reasons to capture and burn a small percentage of the disbursed tokens which will be examined later on.

paperwork handling, stocking, and manufacturing work currently being duplicated by every maker and robotics company.

With one click any KDNA design confirming to the Kambria manufacturing constraints and vetted as being manufacturable can be fabricated, in as little as a few days. The time savings is tremendous and the ability to collaborate increases significantly since work can be immediately duplicated from person to person - just like software.

By sharing knowledge on ultra-lean production, 1...n scaling, metal 3D printing, and other innovative processes not yet common in the industry, members will have a considerable advantage over traditional competitors. The manufacturing alliance will initially be led by OhmniLabs with strong interest from existing partners in Taiwan and Japan. We invite other interested manufacturers to contact us to learn more.

KAT tokens are used for access and payment on the Kambria Manufacturing Network. We pay special attention to reducing friction and making the model work for payments directly in tokens (for highly involved Kambria participants) and for payments in fiat or other cryptocurrencies (ETH, Bitcoin). There are added complexities in that a typical manufacturer will likely be making many fiat purchases from suppliers. We outline our solution to these challenges below.

For payments in KAT, the order can be directly processed by smart contract. The total cost for a particular KDNA is set by the manufacturer and enables the manufacturer to charge an appropriate margin for the work involved. The manufacturer can sell KAT on any exchange to obtain required fiat, or the Kambria Foundation may maintain a reserve (replenished periodically) to facilitate exchange for manufacturers. In addition, the manufacturer's smart contract will send a percent equal to the current community license fee (5% initially) to the Kambria smart contract where it will be divided up as described in the value capture section further on.

For payments in fiat, the order is manually recorded on-chain by the manufacturer. The manufacturer will use the some of the fiat to pay fiat-based expenses directly, but MUST use the same percentage license fee to buy tokens (from any exchange or from the Kambria Foundation reserve) and then send them to the Kambria smart contract for value capture.

As mentioned above, each manufacturer is required to post a stake/deposit of KAT when the smart contract is created to show good faith and involvement in the community. This is also to "pay" for the trust required for the manufacturer to accept and process fiat orders. The exact amount of the deposits and the conditions will be determined at a later date. The first set of manufacturers will accordingly be vetted by the Kambria Foundation but we expect to develop rules to further democratize and allow new manufacturers to join over time.

A future alternative we are considering that still requires trust (but moves the point of trust to the Kambria foundation instead of each manufacturer) is to have a Kambria non-transferrable *entry*

credit similar to Factom's entry credits which can be purchased directly from the Foundation. The resulting fiat is held in a fund by the Foundation. Users then pay the manufacturer on-chain via the manufacturer's smart contract, and the manufacturer can close the loop by sending the credits back to the Foundation which releases the fiat. Careful design of this system can make this entire process transparent to the end user.

We envision that many companies and individuals may start interacting with Kambria by purchasing the latest available robotic platforms to use in fiat, until they want to start making their own customizations and become familiar with the tokens and codebase. This is actually a **significant win for the community** as it establishes a stable flow of fiat and other currencies into KAT.

Also, note that this system is designed to avoid lock-in and maximize the freedom of participants. KDNA encodes comprehensive information so that individuals or companies can go directly to the end suppliers themselves and source and fabricate/assemble all parts. Having this alternative keeps all manufacturers honest. Manufacturers provide time saved, reduced costs from economies of scale, and the ability to then clone or make multiple designs with no more effort than adjusting the number in the order.

OhmniLabs is the founding member of the Kambria Manufacturing Alliance. Thanks to our expertise in design, engineering, and manufacturing, we are able to fulfill orders right at the start of the Kambria deployment.

We prioritize speed, reusability, and efficiency in every process, including supply selection and 3D printing. In fact, we are the first company to bring large scale robotics to production via additive manufacturing. Currently, we have 50 printers capable of printing 120+ Ohmni-sized robots per month. We can add capacity at about 100 robots per month every month with a subteam team of four (scales accordingly). This was achieved through our own design and manufacturing of 3D printers.

2.4. Value Capture and Community Sustainability Utility

KAT tokens are also used to fairly capture the value created by the platform with the intent of making the Kambria community sustainable and not entirely dependent on donations (as is the case for many other large non-profits or open source communities). It is also intended to be a key piece to economically incentivize the community to participate in and add value to Kambria.

Over the life of a robot, we consider three major value capture points:

1. When a robot is manufactured.
2. When a robot is sold or leased for profit/commercial use.
3. When a robot performs a value-adding task that someone is willing to pay for.

Each value capture point is paired with the creation of new value. For instance, prior to the complete robot being manufactured, the individual pieces have little individual value. At the point at which the robot is completed and becomes usable, some of the created value should go to the manufacturer and some of the value returns to the community and individuals that made it possible.

The second capture point is after a robot company has done the work with Kambria to find specific product-market fit. They may have done a lot of spending on understanding customers, branding and marketing, and other costs required to reach the market. Thus, the customer is willing to pay some amount Y for the robot that enables the company to have a margin. A fair part of this value can be captured to reward the community.

The third point is our vision for the future of robotics where robotic labor based on highly-capable robots becomes fungible. Instead of a customer paying for an entire robot, they purchase robot labor on demand (robotics as a service). The robot can submit some privacy-preserving proof of work on-or-off chain as it performs requested tasks, and the user must pay the robot correspondingly. A fair part of the value created by robotic labor can go back to the community.

The value capture mechanism works as follows. For each of the capture points, the Kambria community sets a percentage fair use fee - say 5% at time of manufacture, 5% at time of sale, and 5% of any labor performed. Changes to these fees can be proposed and voted on by the community. All fees are due in KAT.

When a value capture point occurs, the fee is enforced either directly by smart contract (if payment is received in KAT, ether, or potentially other cryptocurrencies) or the receiving entity is obligated to submit the fees to a smart contract (if payment is in fiat) according to the terms of the Kambria license. If necessary, they must purchase tokens at market price on an exchange or via an exchange service facilitated by the Kambria Foundation to obtain the necessary KAT. The on-chain transaction method is preferred, though for practicality we may allow trusted stakers (i.e. robot companies or manufacturers putting up a large enough stake) to handle fiat transactions and comply accordingly.

Fees in the form of KAT tokens are then sent to the Kambria value capture smart contract on chain, and a set of rules handles the splitting. There are three parameters that again can be changed over time, with an estimated initial setting (to be refined through further discussion) in parentheses:

1. Percent returned to entire community (50%)

2. Percent returned to Karma holders as a bonus (40%)
3. Percent held in Community Fund (10%)

As an example, using the above numbers, suppose 100 KAT was collected as a license fee and sent to the value capture contract. 50 KAT would be burned by the contract to reward the community as a whole. 40 KAT would be distributed proportionally to Kambria Karma holders (note: NOT KAT holders) as a bonus that incentivizes the community to work on problems or take actions that are most valuable (i.e. Karma generating) to the community. 10 KAT would go into the Community Fund for the Foundation to manage and redeploy.

Note that the goal with fees again is to keep them reasonable enough that the community is well rewarded for the hard work but the advantage for companies to use Kambria is orders of magnitude greater than if they were to do the work on their own. The time, risk, and cost of building a new robotics team from scratch, spending development dollars, and then having to risk that what was developed can reach the market is an extremely difficult challenge borne by robotics companies today. A reasonable fee for usage should be significantly more palatable by any company looking to transform their business or provide a service to users through robotics.

2.5. Legal Protection Utility

In the ecosystem, an incredible amount of ideation, technology, capital, and experience will be amassed and shared. Keeping the technology and the core platform **open** will be essential to maintaining the pace of rapid innovation. The Kambria Fair Use team will protect the collective work of the community by pursuing compliance and enforcement through legal action against free-riders and violators.

KAT tokens can be used for as both a signaling mechanism and a community fundraising method for legal protection.

Similar to bounties, anyone in the community can flag a possible violation by creating a case (a smart contract) that can track/run votes and receive a pool of staked token donations. For each case it will also link to off-chain collaboration like a wiki page or Slack channels where those interested in the case can confer, collect and share evidence, and coordinate.

The primary signaling mechanism will essentially be similar to a long-running CarbonVote on-chain. We want to incentivize the community to participate in signaling without any economic loss as potential cases may gather momentum for for a long period of time even prior to any legal action being initiated. Every KAT holder can send a zero-value ETH transaction from their wallet to the case's smart contract indicating 'Support' or 'Abstain'. Implicitly, every holder abstains. A mapping is retained of every address in support and at any block the total

KAT held by supporting addresses signals the total level of support. KAT holders are free to change their vote at any time by sending another transaction with their updated vote.

This mechanism also enables public shaming and external interest in the case. If KAT has a large market cap and participation in these votes is high, potentially hundreds of millions of dollars USD could be signaled in support of legal action. This alone may bring a spotlight to violators and incentivize them to come into compliance.

At certain levels of signaled support (may be hardcoded or may be based on relative support level), the Kambria Foundation's team will review and engage legal counsel to make a determination on the cost to the community, chances of success, and expected return given the available data. This information will be made available on the case (off-chain) and votes can be conducted to determine if legal action should proceed now or wait for more support/evidence/etc. This voting occurs with the same mechanism though in this case a specific future block number is selected at which point the tally will decide the outcome.

Once a vote passes to initiate action, donations will be accepted via staked KAT in the smart contract. Based on the estimated costs of the case, once the fundraising amount reaches the threshold, legal action will start. The Kambria Foundation will manage withdrawing (proportionally) from the pool to fund the legal team. As with bounties, spending/withdrawals from the pool will **generate Kambria Karma** in proportion to all the pool participants.

If the case fails, any unspent KAT will be returned proportionally to the stakers. If the case succeeds, the awarded amount in KAT that is owed as a license fee will be returned to the community via the value capture mechanism (above section). The Kambria license should include a reasonable excess penalty when violation of terms is proven. The excess penalty in KAT (minus legal fees) will be returned to the staked pool and proportionally refunded to all contributors. If the award is large then it is entirely possible that the stakers will receive more KAT than they staked, though **no return should be expected by stakers**.

All open source projects deal with the free-rider problem, where those who aren't contributing to the project derive large economic gain that isn't shared with the people having performed the work. The combination of significant advantages to participating in system (share in community reward, access to fast-evolving technology, etc.) and a disadvantage/penalty to being a free-rider should help motivate honest participation.

2.6. Token Holder Perks Program

A large community of roboticists together is valuable resource. Based on this, the Kambria Foundation will negotiate and manage a perks program for all token holders, such as discounted access to makerspaces, coworking spaces, or parts/tools/supplies.

To participate in the program, you only need to hold a minimum of one KAT in a wallet and be able to validate ownership of that wallet. Subsequent tiers ($500+, etc.) will give you access to additional perks/discounts as the Foundation negotiate them. More details will be announced in the future.

3. Team and Advisors

3.1. Founding Members

Thuc Vu, Co-founder, Kambria

Serial entrepreneur, with multiple company acquisitions, the last one by Google. Deep expertise in game theory, tournament design and multi-agent systems. PhD from Stanford and BS from Carnegie Mellon, both in computer science. Social entrepreneur in Vietnam involved in several community projects.

Jared Go, Co-founder, Kambria

Avid maker and roboticist. Previously CTO and founding member at a networks startup. Extensive experience in blockchain, AI, real-time graphics, VR, mechanical engineering and electrical engineering. Stanford Graduate Fellow, BS Carnegie Mellon in computer science.

Tingxi Tan, Co-founder, Kambria

Background in cloud computing, network infrastructure and distributed system design. Active in Crypto Investment since 2010. Built the global scale cloud infrastructure at a networks startup. MSc Computer Science U of Calgary and BSc Applied Math Western University.

3.2. Advisors

Loi Luu, Co-founder, KyberNetwork

Loi Luu is a researcher working on cryptocurrencies, smart contract security and distributed consensus algorithms. He is also a regular invited speaker at Bitcoin and Ethereum workshops such as DevCon2, EDCON.

Loi believes in the force of the Ethereum and Blockchain technology. Much of his work revolves around this community. He developed Oyente, the first open-source security analyzer for Ethereum smart contracts. Loi also cofounded SmartPool, another open source project which embraces decentralization of mining pools in existing cryptocurrency. He continues to champion decentralisation and trustless properties of the Blockchain with KyberNetwork, taking inspiration and developing value for the community.

Karen Hsu, Head of Growth, BlockCypher

Karen Hsu is the Head of Growth at BlockCypher. With over 20 years of experience in software applications and infrastructure, Karen is co-inventor for four patents and worked in a variety of engineering, marketing, and sales roles. At Siebel System, Informatica, Datameer and SugarCRM, she has led teams to bring new products to market. She has also worked closely with financial standards organizations, such as SWIFT, ACORD, and FpML.

George Li, Co-founder, WeTrust

George is an ex-Googler who previously co-founded CottonBrew, a Stanford StartX computer vision company. Prior, he held roles in Corporate Strategy and Infrastructure at Google, and was a consultant at McKinsey. He holds a M.S in Management Science Engineering from Stanford and B.S. in Electrical and Computer Eng from Rutgers.

Manuela Veloso, Head of Machine Learning Department, Carnegie Mellon University

Manuela Veloso is the Herbert A. Simon University Professor in the School of Computer Science at Carnegie Mellon University. She was the President of AAAI (Association for the Advancement of Artificial Intelligence) until 2014, and the co-founder and a Past President of the RoboCup Federation. She is a fellow of AAAI, IEEE, AAAS, and ACM. She is an international expert in artificial intelligence and robotics.

4. Roadmap

4.1. Kambria Platform Roadmap

From day 1, roboticists and companies will be able to collaborate with Kambria by purchasing Ohmni as a platform and customizing the hardware and software themselves.

We will ensure that the Ethereum smart contract and codebase development, as well as the core robotics platform development can proceed in parallel without any hard dependencies.

The individual areas below will also be developed in parallel and iteratively based on feedback from the community:

Codebase

- Complete first pass Git + Ethereum smart contract linkage, along with dapps to view and manage the linkage, account balances, etc.
- Deploy smart contract registry for the Kambria codebase
- Tipping, bounty award mechanisms implemented
- Implement K-DNA compilation/dependency language
- Create the guidelines, standards, and any extra tools for format interchange/collaboration
- Material to guide and help other teams onboard who aren't as familiar with the crypto space to begin participating
- Design codebase/game theoretic new part/process reduction.

Marketplace/Bounties

- Assemble teams of expert roboticists for judging panels
- Establish roadmap and timeframes for issuance of Kambria Foundation bounties
- Implement and iterate on test bounty contracts that allow for the range of flexibility desired: judging, immediate and periodic payouts, multiple rounds, tournament design, etc.
- Ensure the linkage to on-chain bounty contracts and the off-chain wiki, docs, and other materials is clear and usable

Manufacturing

- Build relationships with interested alpha partners and suppliers beyond our existing set
- Develop draft specification 1 of the target supported materials and processes with KMA members
- Develop tools for automated manufacturability assessments for subcomponents of K-DNA
- Implement manufacturer smart contracts to accept K-DNA orders and KAT payment

- Test end to end K-DNA orders with each process flow (3D printing, PCB assembly, etc.)
- Implement linkages to fee capture in smart contract

Value capture

- Implement contract for returning value to both token and karma holders
- Implement community fund smart contracts, managed by Foundation multisig

Legal

- Lock down Kambria source license with legal team and ensure compatibility with other licenses currently being used
- Keep top legal teams on retainer
- Develop legal case smart contracts and mechanisms for signaling, voting, and staking

Phases and Milestones

❖ **January 2018 - June 2018: Kambria Alpha**

❏ Deploy key smart contracts on testnet.

❏ Have GitHub repos linkable to the testnet contracts.

❏ Open up OhmniLabs' 3d printing and waterjet aluminum processes to ensure K-DNA orders are fabricated into real world parts as fast as possible.

❏ Work with roboticists and groups around the world to start sharing KDNA and evolving the tools and processes as needed.

❏ Ohmni robots available to order as a base platform. Continue building out APIs and SDKs based on needs and engage other roboticists in guiding the development.

❏ Start initial bounties for add-ons, enhancements and other valuable technology contributions to Kambria. These may start off-chain and move to on-chain once the smart contracts are ready.

❖ **June 2018 - December 2018: Kambria Beta**

❏ Open up smart contracts on mainnet.

❏ Open up major subcomponents of Ohmni with appropriate licensing transferred from OhmniLabs. Motor drives, touchscreen and display, USB, embedded system, battery charging, vision algorithms, etc.

- ❏ Be able to view these pieces (and those contributed by others) in the code base and remix/work on integrating them into new forms. Collaborate with other teams on demos showing what can be created.
- ❏ Receive real KDNA or fiat orders for these parts on the main chain and send back completed parts.
- ❏ Issue some initial real bounties on mainnet and start bringing the new technology into Kambria codebase for all to share.

❖ **January 2019: Full release**

- ❏ Full release of Ohmni in the Kambria codebase. Entire KDNA and open for full remixing.
- ❏ All bounty systems and Dapps active, released, and usable.

4.2. Kambria Robotics Tech Roadmap

To jumpstart the Kambria codebase, **OhmniLabs will open source and provide complete K-DNA for the entire Ohmni robot**. Ohmni is our state-of-the-art telepresence robot which represents 10 generations of iteration and development over 2 years.

Through Kambria, roboticists can immediately modify Ohmni's K-DNA and customize it for their specific tasks. Part of our motivation for founding Kambria comes from the many requests we received for custom robots. We realized that for many interesting applications, Ohmni was already 98% of the way there and only needed the last 2% customized. Without being an open, modifiable platform, the only alternative for these individuals and companies to have a custom robot would be to build the robot they need from scratch, or manually "hack up" other robots in a non-scalable way. Kambria enables innovative exploration at significantly reduced cost.

OhmniLabs will continue to develop the telepresence product, as well as market, manufacture, support, sell and contribute funds to Kambria. The robot will continue to be called Ohmni. OhmniLabs' goal will be to provide the premiere telepresence robot on the market at the lowest possible cost.

In addition, we will be building and releasing another version of Ohmni on Kambria intended for developers, similar to TurtleBot, Aibo, Nao, and Pepper platforms. However, instead of the long 2- or 3-year cycles, continuous development on Kambria will ensure a release cycle of every 6 months.

OhmniLabs has an internal roadmap to develop the following listed technologies on Kambria, which will be included with advanced versions of the platform as they are developed. These will be the necessary building blocks for more effective and flexible robotics of the future. We will commit to funding this development and driving down the cost of these capabilities.

Navigation/localization/positioning

- Assisted navigation (CMU..)
- Partnering with intel on ZR400 integration
- Autonomous mapping + navigation with high level behavior language
- Cloud map storage, merging, refinement
- Cloud UIs for interactive map making and semantic tagging
- Visual odometry infrastructure (partner)

World interaction

- Low cost 3 DOF arm + high level positioning language
- Low cost 1-2 DOF gripper
- VR teleoperation + predictive haptic feedback (also for training)

Sensory API - vision

- TensorFlow-based transfer learning system - cloud training, local model deployment ultra streamlined

Sensory API - speech

- Tuned hotword detection and command detection
- Scriptable commands and interactions

Audio and camera hardware improvements

- Choice of camera modules, open system (HDR, zoom)
- Distributed mic and positional array
- Ultra-natural sound/voice at low frequencies (subwoofer)

General autonomous behavior

- Neural network for attention model to observe environment and learn.

Embedded system work

- Ultra-high power computation platform (Tegra X1 or laptop class)

Demos

- Demo - Autonomous plant watering
- Demo - Periodic photo inspection of things along a route
- Demo - Tennis ball pick up and organizing
- Demo - tour guide, delivery tasks (cobots-style capabilities)

- Demo - Smart and unobtrusive following and monitoring/checking on person
- Demo - look for an object in certain areas, pick it up and bring it over

Low-cost/telepresence platform v2

- Above enhancements plus floor-to-ceiling height adjustment
- Cost reductions

High capability platform v1

- Open, ZR400, new cameras, etc. etc.

Multi-agent coordination platform

OhmniAPI

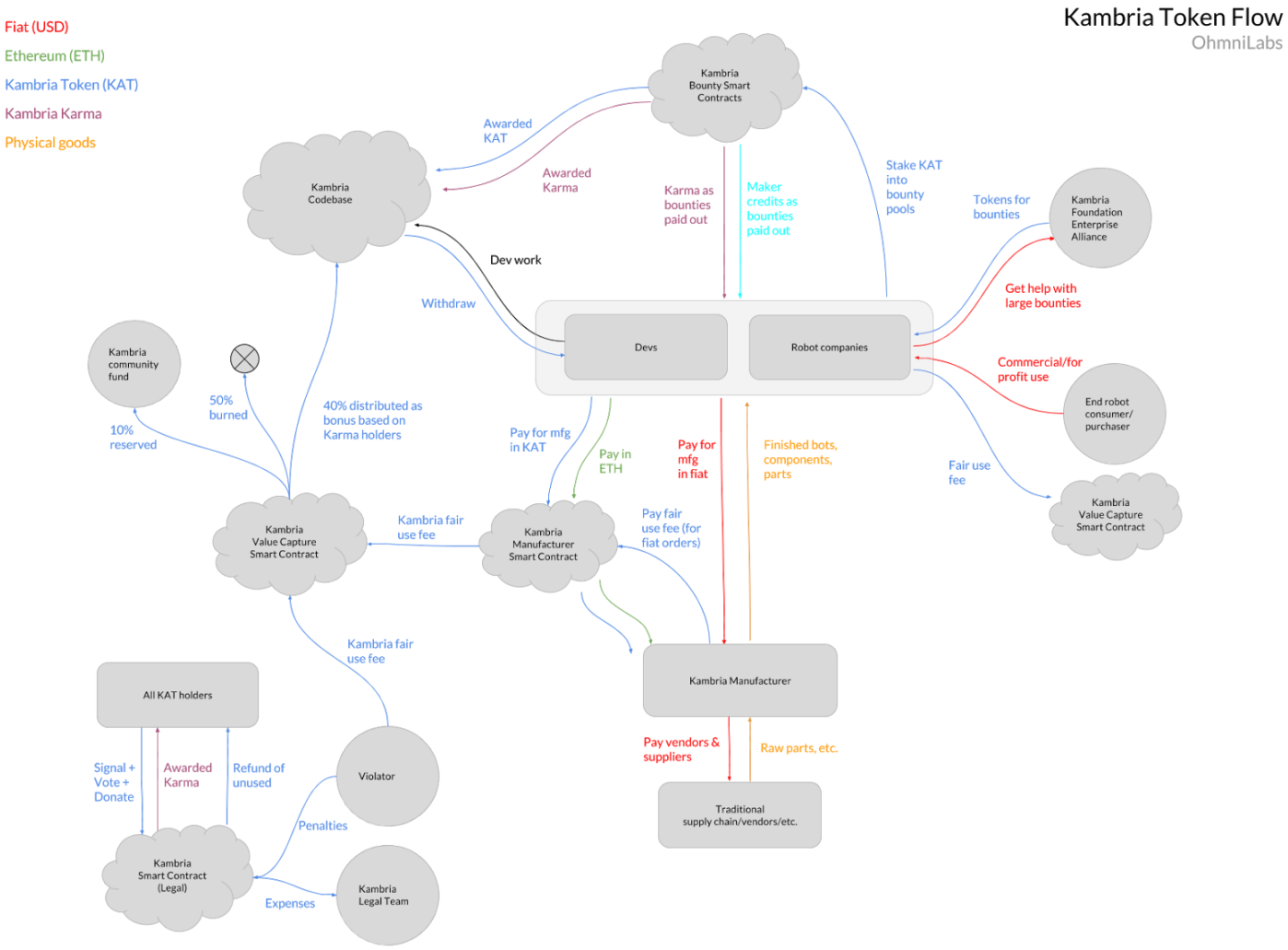
- Integrated motion and actions.
- Couple sensing primitives

Design and form factors

- Explore material like cloth, etc.
- Base form factors like Holonomic drive, outdoor/off-road version, and above water/underwater version (partner with first or other)

5. Appendix

5.1. Detailed Token Flow Diagram



5.2. Ohmni Specs

Physical specs

- Height: 5"
- Weight: 21 lbs.
- Base dimensions: 17.8" x 14.1"
- Front wheels diameter: 6 inch
- Rear wheel diameter: 3 inch

Core system

- Aaeon UP board
- Intel® Atom™ x5-z8350 Processor (2M Cache, 1.44 GHz up to 1.92 GHz) CPU with 64 bit architecture; Quad Core
- 2GB DDR3L-1600
- 16GB eMMC

OS and Software

- Android 7.0, custom modified by OhmniLabs

Connectivity

- WiFi: 802.11a/b/g/n/ac
- Cellular: 4G/LTE via your own WiFi hotspot

Display

- Custom 1280x800 IPS ultra-thin modular display, 10-point touchscreen
- Maximum brightness: 350 nits
- Completely modular - HDMI input for video and USB for touchscreen

Cameras

- 2x 2MP OV2710 based USB cameras
- Field of view: ~160 deg, option for larger

- Pixel size: 3um for low-light sensitivity
- Peak dynamic range: 69dB

Mic and speaker

- Omnidirectional, far-field mic
- DSP with echo cancellation and automatic gain control
- Touch controls for volume and mute

Battery and charging

- 96Wh LiFePO4 battery
- Integrated 20W charger with cell balancing
- Integrated cell protection

Charging dock

- 24V 3A output, 100-240V 50/60Hz AC adapter
- ChargeSense
- Weight/dimensions

Motors

- 30W capable Ohmni Glide Drive design, ultra quiet
- 14-bit absolute rotational odometry via AMS magnetic encoder

Neck servo and USB hub

- Integrated Herkulex DRS-0101 servo
- OhmniLabs 4-port embedded USB 2.0 hub including FTDI serial chip and 5V 3A output

Base LEDs

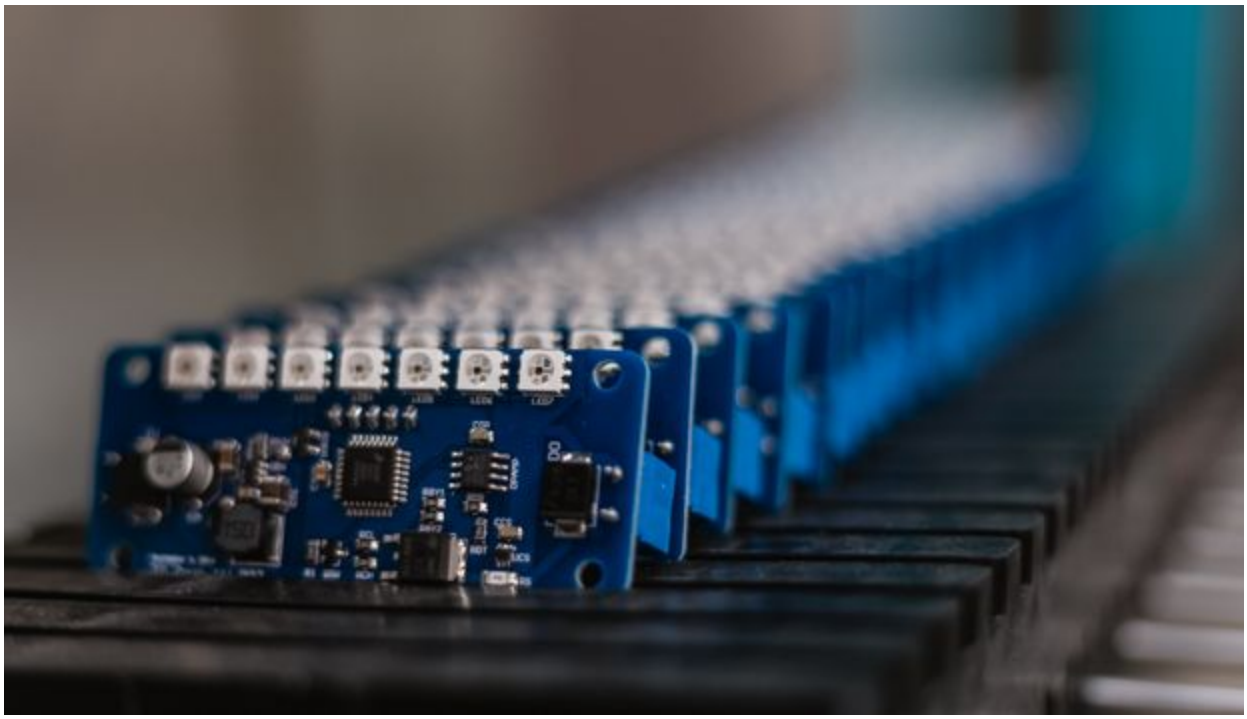
- 3x 24-bit RGB animatable LED strips

5.3. Ohmni Tech Stack

Beyond the design, hardware, and physical components of the robot, we will also be releasing an extensive amount of firmware and software. These include:

- OhmniLabs version of Android-x86 7.0, with custom Intel video acceleration improvements designed for the UP board
- OhmniLabs USB touchscreen firmware, making it possible to re-use low cost multi touch tablet screens with any base embedded system.
- OhmniLabs GlideDrive firmware - brushless motor controllers with custom commutation logic based on an absolute magnetic encoder, supports advanced position and velocity control, torque limiting, odometry, and more.
- OhmniLabs hardware accelerated compositing camera HAL driver
- OhmniLabs vision-based autodocking system
- Ohmni API - high-level, media-rich JS language for programming robot behavior
- Cloud-based control and programming infrastructure

5.4. OhmniLabs Manufacturing Capabilities



Capability to additive manufacture print:

- up to size XYZ
- PLA or PETG

Capability to waterjet cut:

- Aluminum
- Stainless steel
- Acrylic

Capability to laser cut and etch:

- Acrylic

- Felt

Ponoko®

Capability to fabricate cable assemblies (though we try to avoid!)

Capability to fabricate PCBs and do PCB assembly:

- Parts from Digikey or Mouser

Digi-Key ELECTRONICS MOUSER ELECTRONICS

Capability to source hardware/fasteners:

- McMaster, etc. etc.
- Amazon
- Aliexpress

Coming soon: Ability to 3D print metal (a key gamechanger)

Coming soon: Ability to 3D print packaging material.