The Robot Design Game

Come play with us at the **Workshop on Minimality and Trade-offs in Automated Robot Design, on Sunday**. Copies of the game will be awarded to tournament winners.

Robotics is such a wonderfully diverse field!

Think of all the robots you can create by choosing different combinations of sensors, actuators, computing devices, energy sources, behaviors, algorithms, and so on: hardware and software, everything comes together in the field of Robotics.

Given a task, what is the "best" robot to perform it? The cheapest? The one with the highest performance? So many trade-offs exist in this phenomenally large design space.

How can we formalize this co-design problem? Can computers help us? Can we devise automated co-design and co-generation methods?

We created the Robot Design Game to share our excitement about this aspect of Robotics with everybody else. Eventually, this will be a routine problem for an AI to solve, but for now, it is a fun party game for humans.

We hope you have fun playing it, as much as we had creating it! And we'll see you at our workshop to talk about the science behind it.

— Andrea, Hadas, Alli, Dylan, and Jason

The Robot Design Game

The game is loosely modeled on the Iron Chef competition. In Iron Chef, participants are given ingredients, and they need to come up with a recipe. In the Robot Design Game, the participants are given *resources* and they need to create a robot design to perform a given *task* in a given *environment*.

The design goal is represented by “task cards” and “environment cards”. There are “resource cards” that represent the physical and logical components that the players can use to create a design, such as actuators, sensors, computation devices, and so on.

Each player has two private cards, and there is a pot of “common cards” on the table that can be used by everybody. In this aspect, the game is similar to *Texas Hold’em* poker.

In turn, each player can either pick a card (while discarding one, which becomes a common card), or try to describe a solution for the design problem, based on the components on the cards in hand and on the table.

Rather than having a British chef to judge, the

proposed design is subject to peer review. This makes the game much more civilized.

In addition to components, there are special gameplay cards, in the spirit of the game *Magic: The Gathering*.

A more formal description of the rules is in a later section of this booklet, but for now, in brief:

The Robot Design Game =
Iron Chef + Magic: The Gathering
+ Texas Hold'em + robots + peer review.

The cards There are four types of cards in the deck (see Figure 1 on page 6), each type having a different colored back:

1. The **Task** cards define what is the purpose of the robot being designed.
2. The **Environment** cards describe the environment in which the robot is to operate.
3. The **Rewards** cards are used for keeping score during the game.
4. The largest set, **Resource** cards describe elements that can be combined to actually design your robot.

Figure 1: The four types of cards in the game.

(a) **Environment** card

(b) **Task** card

(c) **Resource** card

(d) **Rewards** card

Task cards

The **Task** cards describe the details of the task for which the robot must be designed.

The card description reports the assumptions that may be made.

Figure 2: Example **Task** card

Environment cards

The **Environment** cards describe the situation and surroundings in which the robot must perform its task.

Players should consider the weather conditions and any possible flora and fauna.

Figure 3: Example **Environment** card

Resource cards

What does it take to make a robot? You need sensors, actuators, a computer, and so on. We call all of these “resources”.

These resources cards correspond to physical components:

- **Sensing** cards describe everything that the robot can use to perceive the world.
- **Actuation** cards describe what the robot uses to affect the world.
- **Energetics** cards describe what the robot can use as a power source.
- **Computation** cards describe what computation substrate the robot can use.
- **Communication** cards describe devices and methods the robot can use to communicate.
- **Platforms** cards describe complete robots that can be used as part of the design.

Rather than specific components, the **Form** cards describe aspects of the robot’s appearance or behavior.

The following resources are not physical components, but they can be just as important for the success of a design:

- The **Data** cards describe all prior information and knowledge that the robot can use, such as maps and training data.
- The **Collaborator** cards describe possible colleagues on whom you can count for expertise to help ensure the success of your project.

Finally, there are special gameplay cards that are considered among the resources:

- **Special** cards give special bonuses in the design. These include “multiplier” cards that allow you to boost an existing resource.
- **Instant Effects** cards are special effects that can be used in the gameplay.

Actuation cards

The **Actuation** cards describe the possible robot actuators.

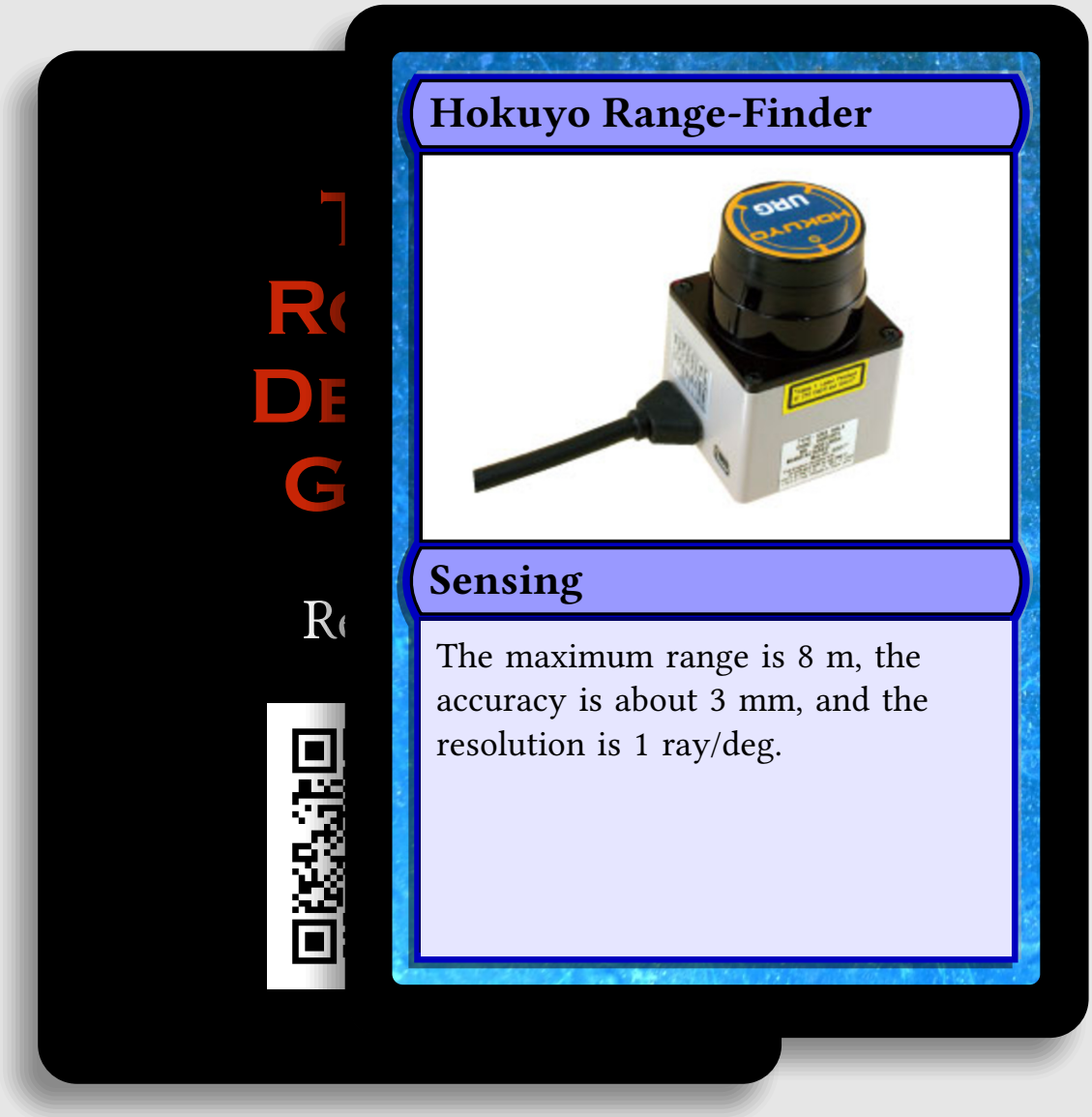
An actuator is any physical device with which the robot can change something in the world.

Figure 4: Example **Actuation** card

Sensing cards

The **Sensing** cards describe the devices and methods that the robot can use for perceiving the world. (An active sensing device, like the Hokuyo range-finder below, is also technically an actuator.)

Figure 5: Example **Sensing** card



Communication cards

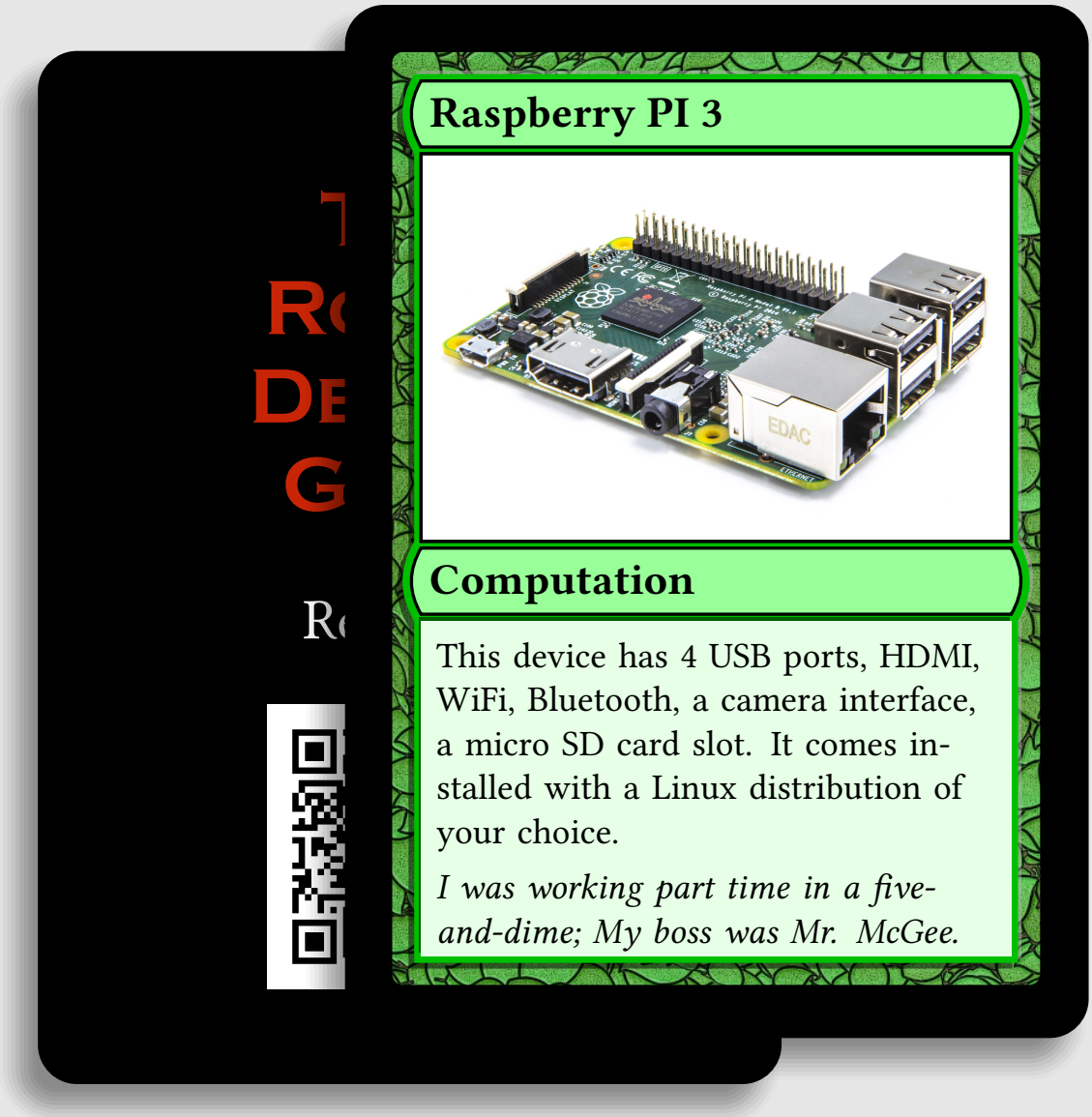
The **Communication** cards describe how the robot can communicate with its team members, operators, or subjects.

Figure 6: Example **Communication** card

Computation cards

The **Computation** cards describe the computation substrate for the robot.

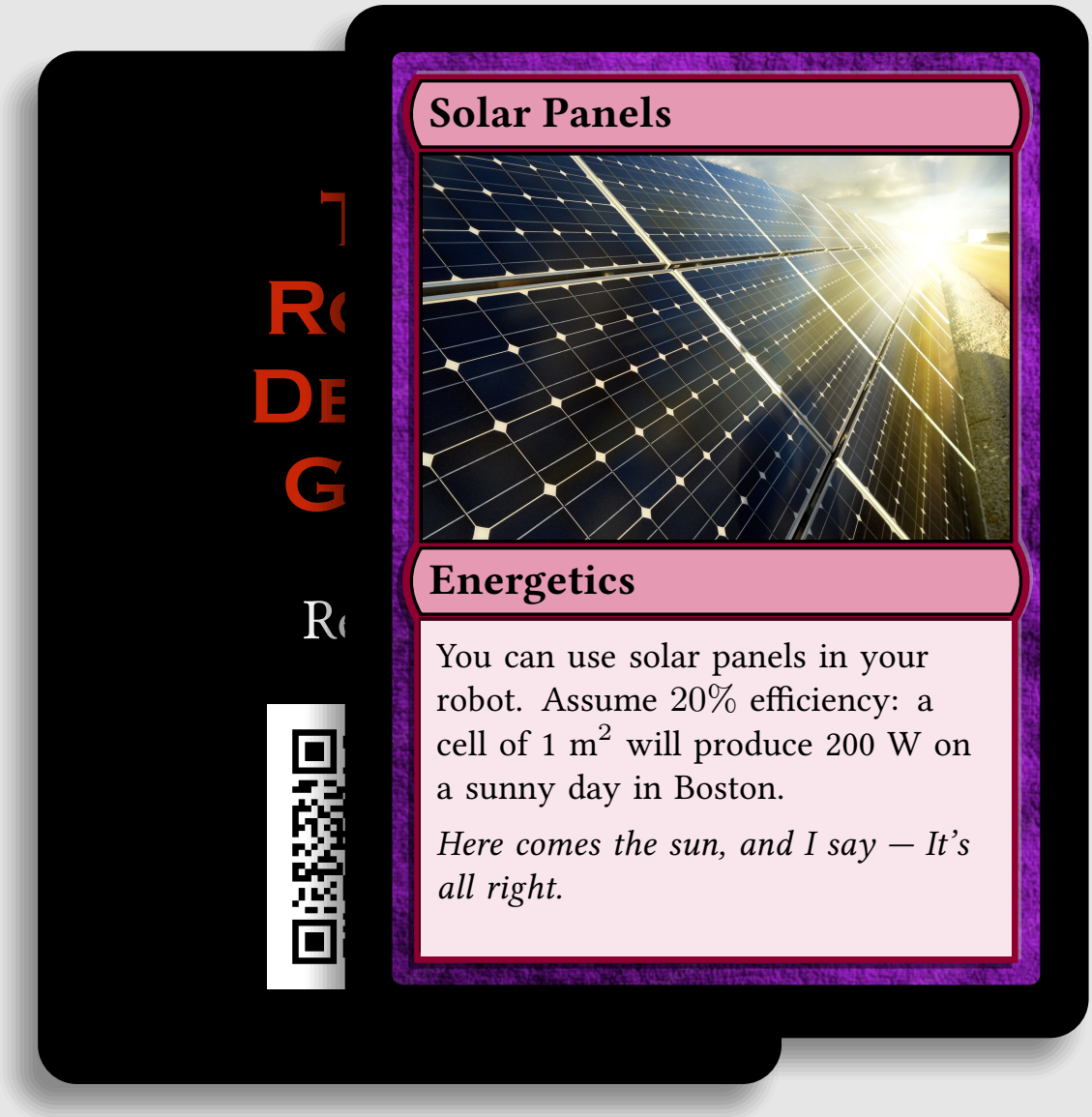
Figure 7: Example **Computation** card



Energetics cards

The **Energetics** cards describe the energy sources that the robot can use.

Figure 8: Example **Energetics** card



Platform cards

The **Platform** cards describe famous robots of the present, the past, and fictional universes.

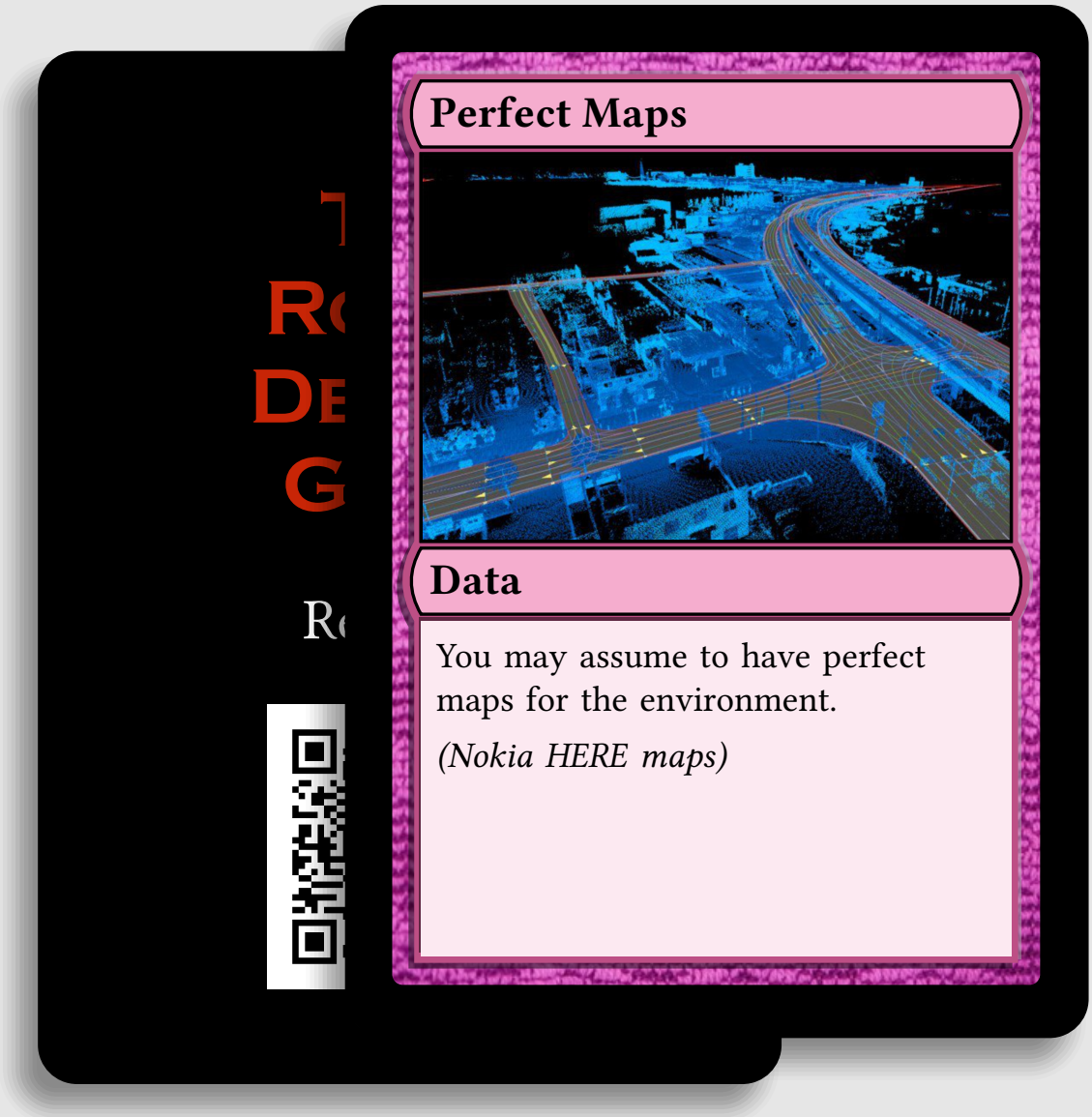
The platforms must be used as a whole, and they cannot be cannibalized for parts.

Figure 9: Example **Platform** card

Data cards

The **Data** cards describe what prior knowledge the robot can use.

Figure 10: Example **Data** card



Form cards

The **Form** cards describe additional appearance and behavioral properties that the robot might have.

Figure 11: Example **Form** card

Collaborator cards

The **Collaborator** cards give you the ability to tap into others's abilities and special powers.

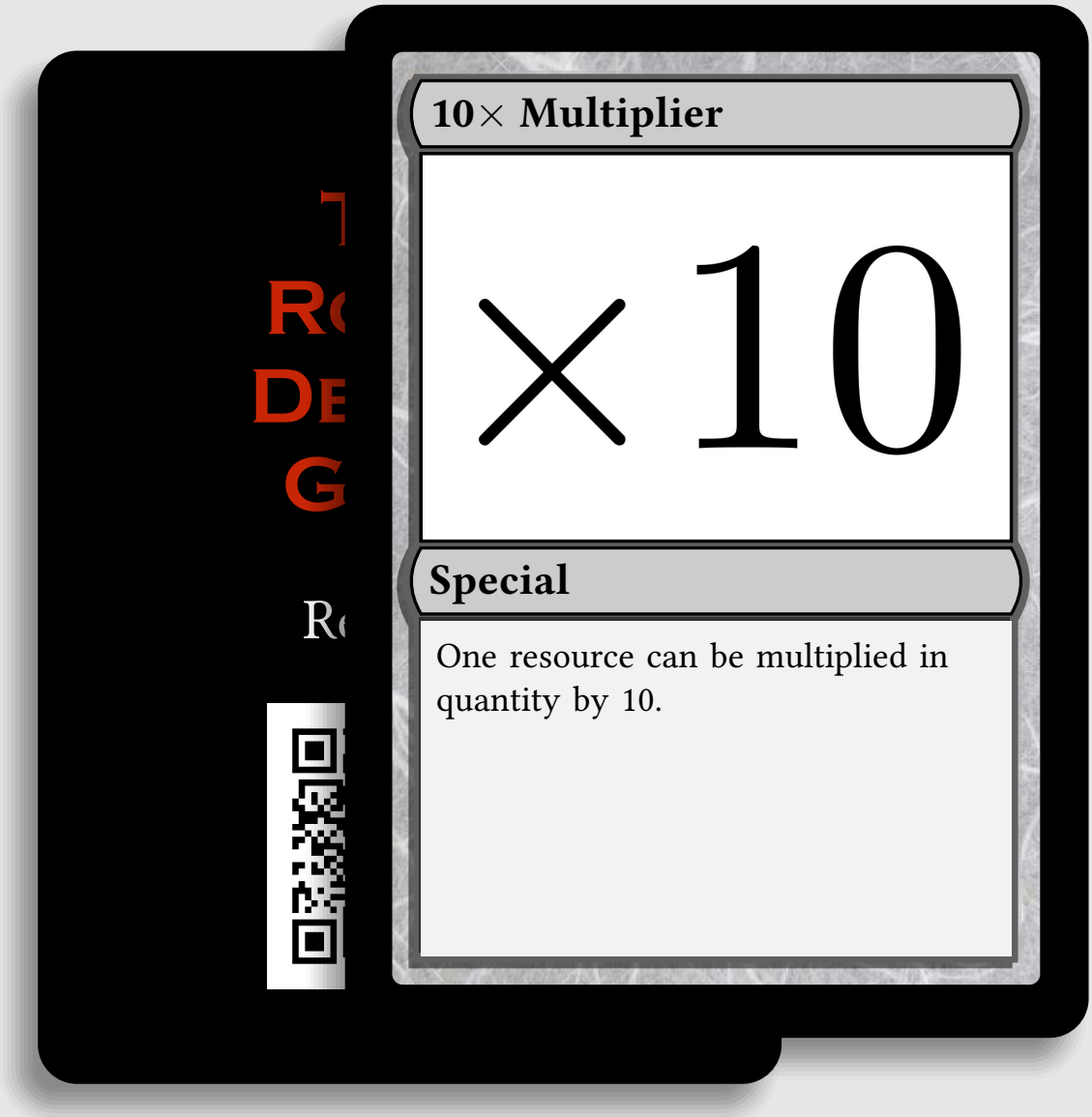
Remember, Science is a collective enterprise!

Figure 12: Example **Collaborator** card

Special cards

The **Special** cards describe special robot abilities or other special bonuses that are applicable to the design. The “multipliers” cards compose associatively (a $2\times$ card and a $5\times$ card together are equivalent to a $10\times$ card).

Figure 13: Example **Special** multiplier card



Instant Effect cards

The **Instant Effect** cards describe special gameplay actions. The cards are discarded after use. If an **Instant Effect** card is the last card in the hand of a person, they get to pick a card from the deck.

Figure 14: Example **Instant Effect** card

The *I Have an Idea!* card

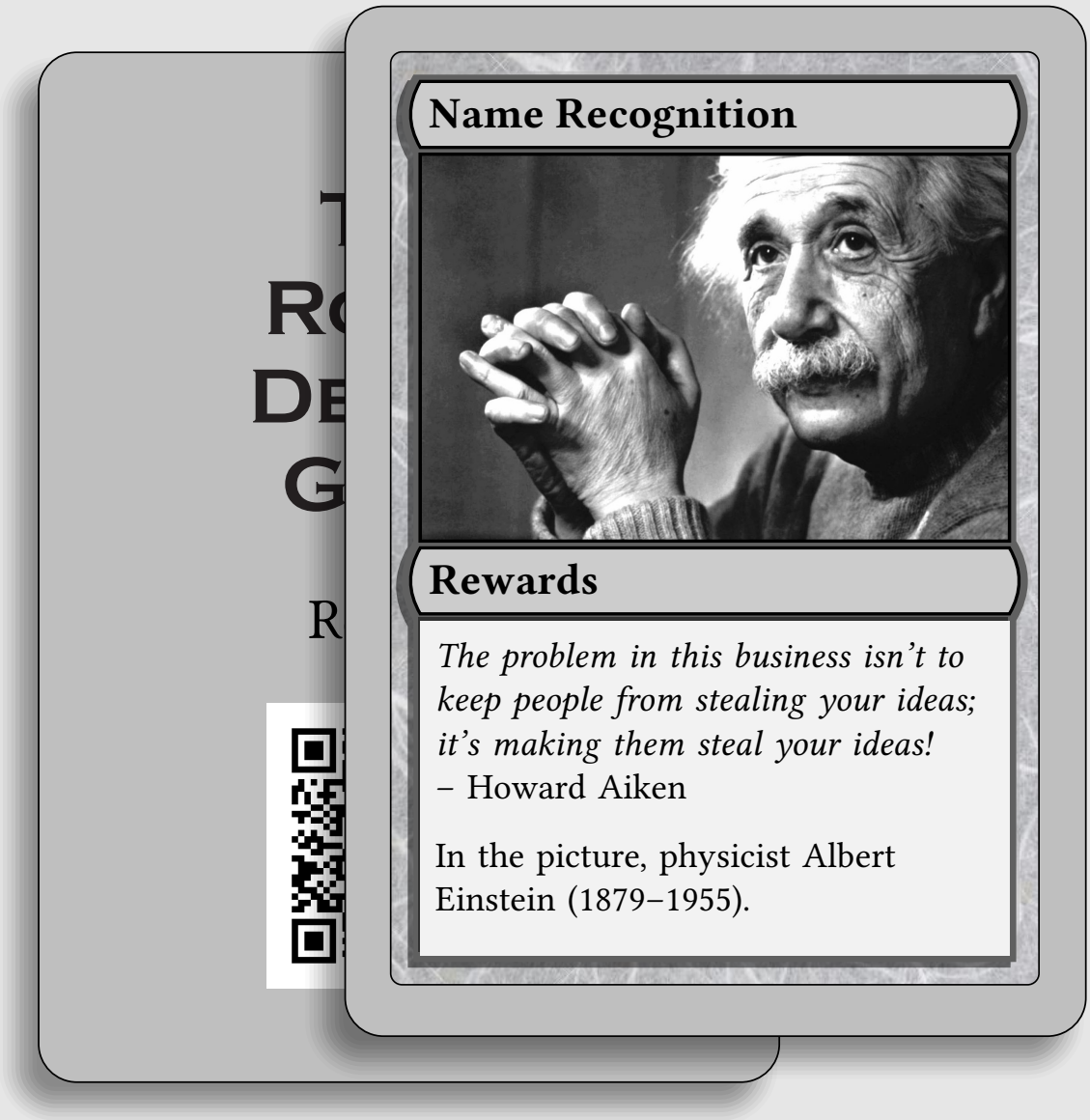
When you play this card, you can create any new card using the provided blanks, and add it randomly to the deck. The card becomes part of all successive games. (Just like in science!)

Figure 15: The *I Have an Idea!* card.

Rewards cards

There are two **Rewards** cards. The *Name Recognition* card is given as a reward to a player that manages to propose a design that passes the peer review phase. The card will help their credibility in the successive rounds.

Figure 16: The *Name Recognition* card



The *Bitterness* card is given as a “reward” if the design is unsuccessful and does not pass peer review. The effect of this card is that the player becomes a “bitter reviewer” in subsequent rounds, which makes their bitter or negative reviews count more.

Figure 17: The *Bitterness* card

The “supplementary materials”

Each card has a QR code on its back. The QR code links to a page containing extra information about the card, which we might call the “supplementary materials”. These include:

- Technical specifications for the device;
- Videos showing the device in action;
- Links to papers and bibliography references.

Players are encouraged to check out the supplemental materials, if they do not know some of the resources they have available.

If the player tries to use a device plainly beyond its capabilities, the design is deemed unfeasible and automatically rejected. (For fictional devices, there is more leeway for creative interpretation.)

The supplementary materials are contained in a wiki that can be publicly edited. Please help us populate the entries!

Accessibility Another use of the QR code is for accessibility to visually impaired people. The card’s page contains a copy of the text shown on the card that can be read by a screen reader.

The rules, in detail

Participants This is a game for 1 dealer, also known as the "associate editor", and $n \geq 2$ players.

The game is the most fun with n between 6 and 8 participants. Fewer players don't give rise to the spontaneous growth of a sense of "community". On the other hand, with many players, rounds can take too long.

Goal The goal of the game is for players to create a robot design using the resource cards. The design is subject to peer review.

One-time setup The following are the instructions for setup of a new game.

1. Make five piles of cards:
   - The **Task** cards.
   - The **Environment** cards.
   - The **Rewards** cards.
   - The **Resource** cards.
   - The blank template cards.
2. Set aside the blank template cards; they are needed only rarely.
3. The associate editor takes the **Rewards** cards and sets them aside, but somewhere ac-

cessible to him/her.

4. The players shuffle and cut the **Task**, the **Environment**, and the **Resource** piles. For the huge **Resource** pile, it is advisable to employ a divide-and-conquer strategy.

At the start of each round This is what happens at the start of each round:

1. The first step is to randomly select a **Task** and an **Environment** card. The associate editor may use any method; for example, having any player choose one card randomly.
2. Together, the chosen **Task** and **Environment** cards define what is the goal for this round. They are placed face up in the center of the table. The other cards from those piles will not be needed for the remainder of this round.
3. The associate editor deals two **Resource** cards face down to each player.
4. The associate editor places one card on the table, face up. That card becomes a common card that anybody can use.

The associate editor decides, possibly randomly, who is the first player to start the game,

and then the round proceeds counterclockwise.[1]

Game turn The player has 15 seconds to pick one of two actions:

1. *Submit a design*: the player tries to win the game by proposing a design. This initiates the "design submission phase", detailed below.
2. *Pick up a card*. The player can pick up a card from the top of the deck. Before this happens, the player must discard one of their cards, face-up, onto the table. The discarded card becomes public and is then available for others to use. The player or the associate editor should describe the card to the other players. After picking up, if the player wishes to *submit a design* they must wait until their next turn.

The game proceeds until a player has successfully submitted a design.

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[1] There is some asymmetry in the game: the first players have few cards on the table, but they also get the first move advantage; later players, instead, have more cards on the table. At this point, it is not clear who is advantaged. Randomness resolves any doubts.

The design submission phase The player must convince the other players that the task has been solved using the cards in their hand, plus those on the table.

This is the sequence of events:

1. The associate editor asks: “What is the title of the paper?” If the title of the paper is not compelling, the associate editor can reject the paper without review. Otherwise the player proceeds to explain their proposed solution.
2. First, the player must declare which cards in their hand (if any) they wish to use for the design. The cards are put on the table and become common cards.
3. Then, the player must declare which cards (if any) they wish to use from the cards on the table. The associate editor temporarily takes away the other cards on the table for the duration of the next step.
4. The player must then “write” the “paper”. The player does this by describing how the proposed solution might solve the current task. All and only the cards that were selected must be used in the design.

Choice of reviewers After the player finishes, it is time for the peer review.

The associate editor selects “reviewers” from the group. The usual number is 3, but it is at the discretion of the associate editor whether to ask for either fewer than or more than 3.

The associate editor can choose the reviewers arbitrarily. The choice can also be random, for example using dice.[2]

Reviews Each reviewer gives a short response to the paper, in the stylistic form of a peer review, raising objections as they see fit, and, of course, commenting on the positive aspects of the proposed design.

It is compulsory for the reviewers to look straight into the eyes of the author while they give their criticism—the review is not valid otherwise.

The author listens in silence and does not answer the criticism at this point; there is a rebuttal phase later.

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[2] A great way for old-school players to show off their d20s.

Instant effects during review phase In this phase, a reviewer may play an **Instant Effect** card, following the particular directions on it.

The card is then discarded. If that is the last card in the hand of a reviewer, they get to pick a card from the deck; the invariant is that a person has at least 1 card and at most 2 cards in their hand.

Rebuttal phase Once all the reviews are in, the associate editor may ask the submitter to respond in a rebuttal phase.

There is no counter-rebuttal phase.

The decision Now it's time for the associate editor to make their decision.

The associate editor must take into account the effect of two cards:

1. Any *Bitterness* card held by a reviewer multiplies by two the weight of their negative opinion (there is no positive opinion multiplier).
2. Any *Name Recognition* card held by the player counts as one positive review.

The associate editor makes a final editorial

decision regarding the paper.

In case of rejection The player loses the cards in that made up the rejected submission, which now join the common cards on the table.

If the player now has zero cards in their hand, then they are dealt a single card.

The author is also awarded a *Bitterness* card.

The round continues with the next player.

In case of acceptance If the paper is accepted, the player wins this round of the game and gains a *Name Recognition* card. This ends the round.

After the round Because the deck is large, we suggest that you avoid reusing the common cards that are on the table. It is rare for a round with 6 people to use more than 40 cards, of which only half are revealed to everybody. Thus, with approximately 200 cards, you can play 10 rounds without seeing the same card twice.

Suggestions for the associate editor

In the Robot Design Game, the role of associate editor is similar to the role of *dungeon master* in Dungeons & Dragons.

The associate editor is responsible for many of the procedural aspects, and has the final word regarding the acceptance of the proposed designs.

The associate editor should use these powers responsibly to make the experience enjoyable to the players: remember, it’s not about you, it’s about the players!

The greatest challenge for the associate editor is getting through the first round of the game, when the players haven’t grasped the technical aspects and the intended tone.

It is valuable to have at least one experienced player who can help clarify the rules, while the associate editor does their job.

Variations of the rules

The default rules explained so far make the Robot Design Game a fun party game.

The following are some suggestions of rules variations suitable for advanced players.

Exclude the Platforms card The **Platforms** cards are very powerful, and you may want to exclude them to have longer gameplay.

Exclude the fictional or implausible cards The game contains many fun cards, such as Lightsaber, Mind Control, Ansible, Dance All Night Long, Mr. Fusion Home Reactor, R2 Astromech Droid, Golem, and so on, as well as the "joker" cards such as Infinite Computation or ∞ multipliers. If you would like a more serious session, exclude all or some of these.

Refine the design objective Another possible variation for advanced players is to introduce refinements of the design objectives. In the standard game, the goal is to find *any feasible design*, and, in practice, the players find solutions that are *barely feasible*, typically these being accepted because of a balance of technical merit and oratory ability.

Alternative objectives can be selected (perhaps randomly) from among the following:

- The design must minimize resource use.
- The design must maximize performance.
- The design must maximize energy efficiency.
- The design must maximize social acceptance.
- The design must make all of us reflect on the human condition.

Help us improve the game

The Robot Design Game evolved into a fun game because of the many suggestions from the people who play-tested the game. Please send us your feedback!

Visit the game's website for instructions on how to contribute to the game, by suggesting changes to the existing cards, by suggesting entirely new cards, by proposing rule variants, or by adding supplementary information to the card's pages (accessible via QR code).

Expansion packs In the future, we will maintain a "generalist" version that balances a bit of everything, and will also create "expansion packs" for particular domains, such as those around aerospace, automotive, or factory setting.

Let us know what you'd be interested in.

Obtaining more decks

Please see the website for instructions on how to get more decks and expansion packs.

Educational use of this game

The Robot Design Game is designed to be fun and educational at all levels. The following are hints for tweaking the game for use in a few different teaching and learning contexts.

Introductory robotics classes In the context of an introductory robotics class, it is probably best to focus on cards that depict concrete hardware components, and leave out the advanced cards such as *Anthropomorphism*.

The **Platform** cards can serve as an historical gallery for the robots of the past.

For undergraduate students, all the cards that have to do with "peer review" or science in general, such as the card *A Russian did it in the 1960s*, may be uninteresting and should probably be removed.

Also consider simplifying the "paper submission" procedure, or use a variant in which the game is cooperative instead of competitive.

Advanced robotics classes In the context of an advanced robotics class, play with all cards, to show off the complexity and the many aspects of robotic designs.

If class time is severely limited so that you can't justify the duration needed to play games, you could just leave the decks around for students to peruse.

They'll likely feel compelled to flip through the cards and will encounter technologies and methods of which they were previously unaware. The QR code on the back of each card brings up a webpage containing videos, datasheets, and references about the content in the card.

Research groups The Robot Design Game is a great game to be played in a research group. Here is a testimonial from Amy Laviers (UIUC):

I learned about your effort last year at (and after) RSS when my graduate student Umer Huzaifa came back with a deck of cards, which my lab has played a few times. We really love both the chance to think about how to formulate ideas and papers, but also the chance to debate about robots more generally that the game provides.

Acknowledgements

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- Jason O’Kane (University of South Carolina).
- Dylan Shell (Texas A&M University);

Many people have contributed by play-testing and suggesting new cards and rules.

Major contributors include Ron Fearing (University of California at Berkeley), Ross Knepper (Cornell), Hadas Kress-Gazit (Cornell), and Amy Laviers (University of Illinois at Urbana-Champaign).

For suggestions of new cards, comments, and news, please visit `robot-design.org`.

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ETH zürich

The July 2017 edition of the game was sponsored by the Institute for Dynamic Systems and Control, part of the Department of Mechanical and Process Engineering (D-MAVT), ETH Zürich. A word from our sponsor:

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